Ontario

Handbook of Training in Mine Rescue and Recovery Operations 1984

Issued by the
Ministry of Labour

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Ontario

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Prepared, published and issued by the Mining Health and Safety Branch of the Ontario Ministry of Labour for the use of men training in Mine Rescue and Recovery operations at the Mine Rescue Stations established in the Province.

First printing	1930	Revised	1968
Revised	1941	Revised	1971
Revised	1951	Revised	1973
Revised	1953	Revised	1975
Revised	1957	Revised	1978
Revised	1961	Revised	1984
Revised	1964		

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Acknowledgement

In equipping the rescue stations established in Ontario and in training men in the use of equipment, the standards adopted by the United States Bureau of Mines were closely followed. Grateful acknowledgement is made for the permission of the bureau to use the information contained in its many publications relating to mine rescue and recovery operations following fires in mines. In preparing this handbook the text in these publications has been freely copied.

Assistance has been rendered by the manufacturers of breathing apparatus and other equipment used in mine rescue work.

Suggestions by a special fire committee set up by the mining industry of Ontario to investigate firefighting operations are gratefully acknowledged and deeply appreciated.

The revisions of the handbook are compiled by the Senior Mine Rescue Officer with the co-operation from the Mine Rescue Officers and other Ministry of Labour staff.

Preface

Purpose

The purpose of the Handbook of Training in Mine Rescue and Recovery Operations is to provide a guide for the training of the personnel constituting mine rescue teams in the knowledge, care and use of apparatus for protection in irrespirable atmospheres, the detection of noxious gases and a general knowledge of accepted procedures to be adopted for rescue and recovery operations during or following a mine fire. It is meant to serve as a reference guide for the members of mine rescue teams and to assist mine operators during mine rescue operations or related incidents.

History

Ontario mine rescue stations and a training program were introduced following a disastrous underground fire at the Hollinger Mine, Timmins, in February 1928. Thirty-nine miners died of asphyxiation. Assistance was requested of the U.S. Bureau of Mines, and their expertise proved the value of a mine rescue organization.

In 1947 the Province of Quebec called upon the Government of Ontario for assistance during a similar occurrence at their East Malartic Gold Mine. Ontario teams from Kirkland Lake, Timmins and Sudbury districts responded. Twelve miners lost their lives.

In 1965 a major fire underground at the McIntyre mine in Timmins involved one hundred and forty Ontario mine rescue men for a week of intensive firefighting operations. The company's teams were involved in clean-up operations for several weeks. Unfortunately, one life was lost. A skiptender

working in excess of two kilometres from the fire was overcome by carbon monoxide gas without an awareness of the situation.

These three major incidents have proved how disastrous, in lives lost, and expensive through loss of production and jobs, an underground mine fire can be.

Emergencies have proved the need for a co-ordinated and standardized program in Ontario and have been instrumental in shaping the organization we have today.

Authorization

The authority for organization and financing of the mine rescue stations and the assignment of responsibilities are contained in the regulation made under the Occupational Health and Safety Act Revised Statutes of Ontario, 1980, Chapter 321, revised Regulations of Ontario, 1980, Regulation 694.

16 (1) Mine rescue stations may be established, equipped, operated and maintained in such locations as the Minister considers advisable.

(2) The cost of establishing, equipping, operating and maintaining the mine rescue stations shall be paid out of the Consolidated Revenue Fund in the first instance and shall be reimbursed quarterly by the Workers' Compensation Board from money assessed and levied by the Board upon employers in the mining industry to defray the cost certified by the Deputy Minister.

(3) Moneys received from the sale or disposal of any equipment, buildings or machinery used in mine rescue or any handbooks or publications on mine rescue shall be credited against the cost of mine rescue stations.

(4) A mine rescue station and the training of members of a mine rescue crew shall be under the direction of a mine rescue officer appointed by the Ministry.

(5) A mine rescue crew member shall possess such physical qualifications, and establish competency in mine rescue skills as described in the Handbook of Training in Mine Rescue and Recovery Operations, current edition, issued by the Ministry.

(6) The owner of a mine shall make available training facilities and workers to be taught and trained in mine rescue work at the expense of the owner.

(7) A mine rescue operation at a mine shall be under the direction of the supervisor in charge of the mine and the costs of the rescue operation shall be at the expense of the owner of the mine.

(8) Notice shall be given immediately to a mine rescue officer and to an engineer of the Ministry when the services of a mine rescue crew are required.

Organization

Ontario's mine rescue program represents a co-operative effort between the individual mining companies and the Ministry of Labour. Mining companies pay the full cost, but the administration is the responsibility of the Ministry of Labour.

The province is divided into eight districts, with eight Mine Rescue Officers responsible for all training and maintenance of mine rescue equipment. A Senior Mine Rescue Officer is responsible for the co-ordination, standardization and activities of the Mine Rescue Officers.

Equipment is serviced from the main station and distributed between the main station and company mine rescue stations.

Listed below are the eight districts and the addresses of the Mine Rescue Officers.

Senior Mine Rescue Officer	260 Cedar Street Sudbury, Ont. P3B 3X2	(705) 675-4468 Res. (705) 560-1465
Elliot Lake	50 Hillside Dr. N. Elliot Lake, Ont. P2N 2E8	(705) 567-4606
Onaping	Levack Highway Box 338, Onaping, Ont. P0M 2R0	(705) 966-3844
Red Lake	431 Dickenson Road Box 368 Balmertown, Ont. P0V 1C0	(807) 735-2331
Southern Ontario (covered by) —	Sudbury	(705) 566-4344

Sudbury	1494 Frood Road Box 65 Sudbury, Ont. P3E 4N3	(705) 566-4344
Thunder Bay	1551 Arthur St. W. R.R. #2 Thunder Bay, Ont. P7C 4V1	(807) 577-5321
Timmins	Highway 101 Box 1096 Timmins, Ont. P4N 7J3	(705) 264-7511

Mine Rescue Stations and Sub-Stations — 1984

Distribution of Drager BG 174

Main Station	Sub-Station	BG 174	Total
Elliot Lake		18	42
	Denison	6	
	Panel	6	
	Stanleigh	6	
	Quirke	6	
Kirkland Lake		18	48
	Cobalt		6
	Castle		6
	Ross		6
	Macassa		6
	Kerr Addison		6
	(Canadian Gypsum)	(6)	
	(Domtar Gypsum)	(6)	(18)
	(Westroc Gypsum)	(6)	
Onaping		18	40
	Lockerby	10	
	Strathcona	6	
	Fraser	6	
Red Lake		14	49
	Campbell	10	
	Dickenson	10	
	Mattabi	15	
Southern Ontario			
(from Kirkland			42
Lake)	Canadian Gypsum	6	
	Domtar Gypsum	6	
	Westroc Gypsum	6	
(from Sudbury)	Canadian Salt Co.	12	
	Domtar-Sifto Salt	12	

Sudbury		24	48
	Falconbridge	12	
	Creighton	12	
	(Canadian Salt Co.)	(12)	(24)
	(Domtar Salt)	(12)	
Thunder Bay		6	54
	Algoma Ore Division	15	
	Noranda Geco	15	
	Renabie	6	
	Shebandowan	12	
Timmins		18	46
	Pamour No. 1	6	
	Pamour Schumacher	6	
	Kidd Creek	10	
	Dome	6	

( ) Parenthesis indicates station coverage

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Chapter VIII. Ontario Mine Rescue Emergency Organization

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List of Illustrations

Chapter I

Selection, Qualifications and Training of Mine Rescue Personnel

Selection

The successful selection of suitable personnel for work in mine rescue and recovery operations depends on the judgment of the mine management, the examining physician and the Mine Rescue Officer.

Examination for Medical Qualifications

In order to be certain that only persons sound of body, normal in mind and physically fit are selected for training in the use of self-contained oxygen breathing apparatus, they should be examined by a physician and certified to be in prescribed physical and mental condition before training begins and at yearly intervals thereafter if they remain in active training.

The Medical Report form for an applicant for training in mine rescue and recovery operations consists of two sections; one is retained by the employer and one is kept at the Mine Rescue Station, following certification by the examining physician. *(see Figures 1-4)*

Discussion of Medical Requirements

Miners vary greatly in physique and no definite standard can be laid down as to height, weight or chest measurement. Much must be left to the examining physician. It is, however, emphasized that the applicant must be of average or better physique.

New trainees should not be under 21 years of age or over 45.

Men under 21 years of age or over 50 should not actively engage in rescue and recovery work which involves wearing oxygen breathing apparatus.

Although no definite limits can be set, experience has shown that men from 21 to 36 years of age, from 5 ft. 6 in. to 6 ft. (165 to 183 cm) in height, and weighing from 140 to 180 lb. (64 to 82 kg) are the most satisfactory.

The subject must have at least 20/40 uncorrected vision in each eye, and have acceptable hearing in each ear.

Assurance of Qualifications for Duties

The Mine Rescue Officer should be assured that a candidate has good potential for developing into a qualified member of a mine rescue team.

To qualify as a member of a standard mine rescue team a person should have successfully completed both the basic and standard courses of training as outlined in this chapter. Physical and mental qualifications are very important. A member of a rescue team should be —

1. not younger than 21 years of age, nor over 45;
2. in good health, and physically fit;
3. of temperate habits;
4. of sound mind;
5. clean shaven, with no facial hair to interfere with the facemask of the apparatus worn;
6. possessed of good vision and hearing;
7. calm and self-controlled in emergency and danger;
8. have good judgment and initiative;
9. capable of performing long and arduous physical labour;

10. familiar with underground mining conditions and practice;

11. conversant with the practices of First Aid;

12. able to communicate in the English language.

Ontario Ministry of Labour

Training in Mine Rescue and Recovery Operations

Medical Report

Name	
Date of Birth	Telephone No.
Address	
Occupation	Employment No.
Employer	
Address	
Next of Kin	Relationship
Address	

Applicant should be examined by a physician before taking Mine Rescue Training. To be filled in by employer and given to the Mine Rescue Superintendent on completion of the physical examination of the applicant.

Retain this portion at Mine Rescue Station

0372 (6/78)

Fig. 1 — First Portion of Medical Report Form (Retained by Mine Rescue Station)

Name

The above named applicant has been examined by me and in my opinion should be capable of performing the duties necessary in Mine Rescue Work while wearing breathing apparatus.

Signature of examining physician	Date
Address	

Training Record

Mining Rescue Station

Course of Training	Date Completed
Basic	
Standard	
Advanced	
Supervisory	
Refresher	

Station Superintendent

These certificates shall be renewed at the end of one year from date thereof.

Fig. 2 — Reverse Side of First Portion of Medical Report (Retained by Mine Rescue Station)

Ontario
Ministry of
Labour

Training in Mine Rescue
and Recovery Operations

Medical Report

Name	
Date of Birth	Telephone No.
Address	
Occupation	Employment No.
Employer	
Address	
Next of Kin	Relationship
Address	

Applicant should be examined by a physician before taking Mine Rescue Training. To be filled in by employer and given to the Mine Rescue Superintendent on completion of the physical examination of the applicant.

This portion to be retained by employer

0372 (6/78)

Fig. 3 — Second Portion of Medical Report. Duplicate of Side Shown in Fig. 1 (Retained by Employer)

Medical Report

Age	Weight	Height
Vision: Right eye		Left eye
Hearing: Right ear		Left ear
Nose:		
Teeth:		
Throat:		
Chest: Expanded		Deflated
Heart: Normal	After Exercise	After 2 min. rest
Blood Pressure:		
Abdomen: scars		
Extremeties:		
Nervous or Composed:		

The applicant is in my opinion of good physique and sound health and should be suitable for training in Mine Rescue Work and the wearing of breathing apparatus.

Signed	Date
Address	

To be filled in by examining physician and retained by employer.

Fig. 4 — Reverse Side of Second Portion of Medical Report. (Retained by Employer)

Training Courses: General Setup of Courses

Formal training in mine rescue and recovery operations consists of five courses. The first three are for the regular mine rescue teams, and the fourth and fifth are for mine supervisory staff and management. Additional special refresher courses are given as needed to maintain efficiency.

Chart of Training Courses, Training Personnel, Certificates and Seals

Training Course	Personnel Trained	Award
1 Basic Training	Supervisors, Rescue Teams	Ontario Ministry of Labour - Basic Certificate
2 (a) Standard Training (b) Modified Standard Training	Rescue Teams Supervisors	Red Seal to be Affixed to Certificate
3 Advanced Training	Rescue Teams	Gold Seal to be Affixed to Certificate
4 Supervisory Staff	Supervisors	Gold Supervisory Seal to be Affixed to Certificate
5 Management Course	Senior Mine Supervision	Certificate and Seal
6 Refresher Course	All Personnel	Recorded

Each course must be completed and an examination (written and practical) passed before the next course is taken.

The training schedules for these courses are outlined in this chapter. The schedules may be modified to suit local conditions, but the quality of the training should not be allowed to suffer.

Basic Training

The estimated total training time required for this course is 24 hours. It consists mainly of lectures with the practical introduction of mine rescue apparatus.

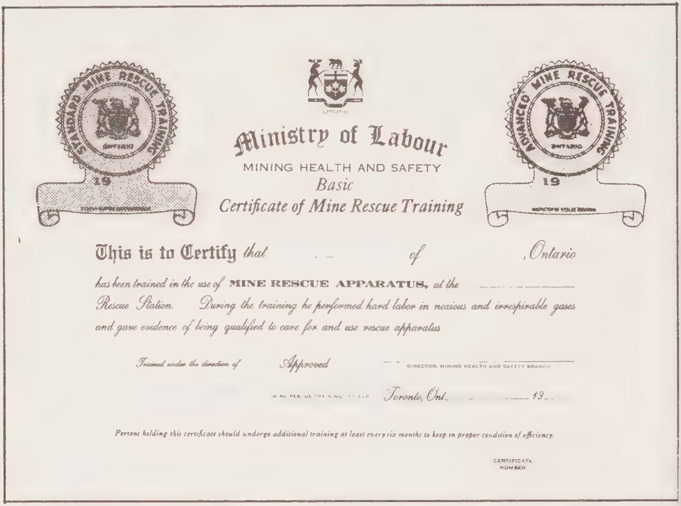


Fig. 5 — Basic Certificate Showing Seals Attached

Basic Training is the foundation course for all mine rescue training. It is essential that all rescue men acquire a knowledge of the following:

1. The object of rescue and recovery work.
2. The constituents and properties of normal air and gases which may be encountered in abnormal circumstances in mines.
3. Methods of detection of these gases.

4. Methods of protection of persons travelling in atmospheres contaminated by noxious gases.

5. A preliminary training period in the actual wearing of the protective devices.

An examination will be held on the work covered. The examination will be set by the Mine Rescue Officer.

A Basic Mine Rescue Course is normally held on three consecutive days. The outline of the course is as follows:

First Day — First Period

Enrolment of class and securing of data on class members.

Theory

An outline of the objects of Mine Rescue and Recovery work.
Air and variations of mine air from normal.
Various gases found in mine air and their effects on persons.
Treatment for gas poisoning.
Methods of detection of various gases found in mines.
Methods of protection against toxic or noxious gases; personal protection when testing for gas; gas masks and other breathing apparatus.

Question Period

During this period the class will be expected to answer questions on the subjects covered in the lecture and should be urged to ask questions.

First Day — Second Period

Type N Gas Mask
Use and limitations
Field Testing
Wearing apparatus
Precautions while wearing Type N mask

Oxygen Self Rescuer OXY-SR 45 M
Use and limitations
Field Testing
Wearing apparatus

Flame Safety Lamp
Cleaning, filling, use and maintenance
Testing lamp
Demonstrate with Lamp Testing Cabinet

Drager Gas Detector
Testing, use and maintenance

Question Period

Second Day — First Period

Self-contained oxygen breathing apparatus Drager BG 174
The principal parts of the apparatus and their functions
The valves, their location, purpose and action
The absorbent used and its functions
The high pressure gauge
Demonstration of the principal parts
Demonstration of the field tests necessary before wearing the apparatus
Explanation of Universal Leak Tester and Negative Leak Tester, as used in the testing of the Drager BG 174 apparatus.
Leaks in apparatus and how to locate them.

Practical

Field test of BG 174 by the individual

Question Period

Second Day — Second Period

Field Test of BG 174 by the individual
- Practise with the apparatus
- Wearing and adjusting the apparatus for comfort
- Getting under oxygen
- Walking as a team while under oxygen
- The necessity of team discipline
- Getting out of oxygen
- Remove apparatus and servicing

Third Day — First Period

Field testing of standard equipment
Field testing of BG 174's

Getting under oxygen
- Practise standard drills
- Use of link line
- Standard code of signals
- Marking route of travel

Practice — Emergency drills
- Use of bypass valve in emergency
- Resuscitation of team member
- Carrying an injured team member
- Stretcher drill
- Interchange of oxygen bottles
- Service the apparatus

Third Day — Second Period

Examination 4 hours

The examination may be conducted at the rescue station or other convenient place. It consists of two parts, practical and written.

The practical examination covers the wearing of the Type N

and other masks, the Drager apparatus, and the use of various detectors.

The written examination covers the subjects taught during the course.

Standard Training

The training time required for this course is 24 hours.

Classes are normally conducted in three consecutive days, within 30 days of completing Basic Training.

Standard Training in Mine Rescue and Recovery Operations is a continuation of Basic Training. The course consists mainly of training in the wearing of the breathing apparatus in irrespirable atmospheres and further instruction and practice in the problems that arise in mine rescue operations, team work, establishing a fresh air base, building various types of barricades, travelling in smoke, testing for gases, and other related matters.

At the completion of this course an examination will be given, and successful candidates will be granted the red Standard Training Seal affixed to their Basic Training Certificates. The examination will be set by the Mine Rescue Officer.

First Day — First Period

Class enrolment and organization of teams

Explanation of Standard Training and what is expected of men taking this training.

Testing and wearing Drager apparatus
Problems in travelling as a team.

The team members, properly dressed and equipped with Drager oxygen breathing apparatus, should make the field tests as a team.

Fig. 6 — Standard Seal (red)

The team should then proceed to the selected fresh air base underground. The ideal place for this work is a drift or crosscut approximately 500 to 700 metres in length with several openings leading from it.

Team discipline, instruction and practice.

Instruction and practice in the following matters should be given: how to walk as a team; how and why team members are fastened together when travelling in smoky atmospheres; passing the team through a door; rates of travel and how to mark route and end of route in atmospheres of different visibilities; travelling by sense of touch; how track switches in the route travelled should be turned.

The foregoing procedure should be repeated until everyone is familiar with each routine.

Return to lecture room.

Recharge oxygen bottles and empty regenerators, sterilize apparatus, replace full oxygen bottles in apparatus.

First Day — Second Period

Demand types of breathing apparatus including testing, wearing, cascading and connecting to jumbo cylinder
Various methods of gas detection
Demonstration of gas testing cabinet, testing for methane
Locations, requirements and establishing of a fresh air base
Organization at time of a mine fire
Discussion of fire procedures
Duties and responsibilities of a team captain
Use of mine rescue team guides.

Question Period

Second Day — First Period

The team wearing BG 174's will proceed underground, establish a fresh air base, get under oxygen and practice the following drills and procedures in light smoke if possible:

Stretcher drill
Distress drill, carrying team member
Fire hose drill
Communications between fresh air base and team
Changing oxygen bottles between team members

Go to surface, service the equipment.

Second Day — Second Period

Station test BG 174's
Demonstrate use of oxygen pump
Lecture on refuge stations and barricades
Firefighting: fire extinguishers, foam machine, other methods.

Question period

Third Day — First Period

Underground in heavy smoke
This drill will simulate an actual emergency
- Organizing of teams
- Establishing fresh air base
- Team briefing
- Rescuing of victims
- Fighting of fires
- Ventilation and recovery of mine workings

Reporting by captain and briefing officer.

Third Day — Second Period

Discuss case histories
Review.

Question period

Written Examination

Fig. 7 — Advanced Seal (gold)

Advanced Training

Advanced Training will be given to those men who have completed the Basic and Standard Training Courses and have been granted the Certificate and Seal in recognition.

A minimum training period of 2 years must elapse before a team member is eligible to take the Advanced Examination. This enables each trainee to become familiar with all phases of mine rescue training through attendance at 12 training periods following standard training.

The examination for this course will be set and supervised by the Senior Mine Rescue Officer.

Successful candidates will be granted a gold seal to be affixed to their certificates.

Supervisory Staff Training

Supervisors

This course conducted by the Senior Mine Rescue Officer, requires 16 hours and is designed for Supervisors, who should be trained so that they are able to supervise an emergency which involves the use of mine rescue teams and the use of mine rescue apparatus.

At the completion of the course an examination will be held and a seal to be affixed to his Basic Training Certificate will be issued to each successful candidate.

Fig. 8 — Supervisory Seal (gold)

The course consists of three parts

Basic Training, as already outlined. Lectures and practice.

Modified Standard Training. Lectures and practice in the care, use and maintenance of respiratory breathing apparatus, and the detection of mine gases and their physiological effects.

Special Supervisory Training. Such lectures and practice as may be found applicable to supervisory problems in mine rescue and recovery operations in co-operation with the mine management.

Management Course

This course, specifically for management personnel requires 24 hours.

It is designed to give management a thorough knowledge of the Ontario mine rescue program and management's respon-

sibilities during emergencies. It is a modified basic, standard and supervisory course with written examination, which could qualify the participant for a certificate with management seal attached.

Refresher Courses

All active mine rescue teams should receive at least an 8-hour refresher course every two months. This course comprising of the Standard and Advanced Training is found necessary in order to maintain the efficiency of the mine rescue and recovery organization.

All other trainees such as supervisors and specialists should receive a refresher course, particularly in the wearing of apparatus, every six months.

Chapter II

Mine Gases, Their Occurrences, Properties, Effects on Human Beings, and Treatment of Persons Affected by Them

Air

Air is the transparent medium surrounding the earth, in which plants, animals, and human beings live and breathe. It is a mixture of several gases, which, though ordinarily invisible, can be weighed, compressed to a liquid, or frozen to a solid.

Pure, dry air at sea level contains by volume the following gases: oxygen (O_2) 20.94 per cent; nitrogen (N_2) 78.09 per cent; carbon dioxide (CO_2) 0.03 per cent; and argon 0.94 per cent. Traces of other gases such as hydrogen, helium, etc., are also present.

The air in a well ventilated mine seldom shows any depletion of the oxygen content.

Mine air may be contaminated by the presence of other gases such as carbon monoxide, sulphur dioxide, hydrogen sulphide, methane and oxides of nitrogen. The presence of these gases may be due to any of the following:

1. after effects of blasting or other explosions;
2. after effects of mine fires;
3. exudations from ore or country rock, as with methane;
4. decay of mine timber;
5. absorption of oxygen by water, timber or ore;
6. use of diesel motors underground.

Except in the case of fire, positive ventilating currents of sufficient quantity will prevent any dangerous accumulation of these gases. Gases may affect people either by their combustible, explosive, or toxic qualities or, if inert, by the displacement of oxygen. The effects may be due to varying atmospheric conditions, and may be classified as follows:

Note: In this manual, all references to percentage of gases are per cent by volume.

Altitude	Breathing becomes more laborious as the altitude increases. This is not dangerous unless conditions are extreme or the labour arduous.
Temperature	High temperatures in excess of body temperature with low humidity may not be dangerous except from the blistering effect of heat.
Humidity	High temperatures with high humidity may cause considerable discomfort and weakness.
Impure Air	(**a**) Air deficient in oxygen may not be dangerous unless the oxygen content is below 16 per cent, or unless the oxygen has been displaced by toxic gases. (**b**) Non-toxic gaseous impurities are not dangerous unless gases have displaced the oxygen content to below 16 per cent. (**c**) Some toxic gaseous impurities, even in very low concentrations, have deadly effects. Effects may be sudden or gradual according to the concentration of impurity. See descriptions of individual gases for further details.

Oxygen (O_2)

Oxygen, a colourless, odourless, tasteless gas, is the most important constituent of air. It is necessary for the support of life and combustion. Men breathe most easily and work best when the air contains approximately 21 per cent of oxygen. When the oxygen content is about 17 per cent, men at work will breathe a little faster and more deeply. The effect is about the same as when going from sea level to an altitude of 1,700 metres.

Men breathing air containing as little as 15 per cent of oxygen usually become dizzy, notice a buzzing in the ears, have a rapid heartbeat, and may suffer headaches. Very few men are free from these symptoms when the oxygen in the air falls to 10 per cent.

The flame of a safety lamp or candle is extinguished when the oxygen falls to about 16.0 per cent. A carbide lamp flame will burn in an atmosphere containing as little as 12.5 per cent of oxygen.

Since oxygen is more soluble than nitrogen in water, air in a confined area when exposed to water will probably have a lowered oxygen content. As an example, the oxygen content of the air from the hydraulic compressed air plant which was located at the Ragged Chutes on the Montreal River, Cobalt, Ontario was lowered to about 17.7 per cent of oxygen and a consequent rise in nitrogen content occurred.

Oxygen percentage higher than the normal 20 to 21 per cent, apparently has no injurious effect on men. This is found to be the case in the use of self-contained oxygen breathing apparatus even with successive periods of wear. Oxygen in high percentages, as used with the oxygen breathing apparatus, helps men to work with less fatigue. However it is dangerous to breathe pure oxygen while the body is subjected to greater than 100 kilopascals (kPa) above normal pressure, such as in caisson or tunnel work, for even very short periods of time. (U.S. Navy

Diving Manual). Lorrain Smith, the well known physicist, states that irritating effects of oxygen are only found in human beings after they have been exposed for 48 hours or more in an atmosphere containing 80 per cent of oxygen, at normal atmospheric pressure.

An oxygen enriched atmosphere creates a potentially serious fire hazard. This condition may be created when using oxygen breathing apparatus or other oxygen equipment, particularly in confined spaces such as tanks, wells or enclosed rooms.

The effects of oxygen deficiency near or below sea level are the same as those due to the reduction of oxygen at high altitudes. At approximately 7 per cent of oxygen the face becomes leaden in colour, the mind becomes confused, and the senses dulled. When there is no oxygen in the atmosphere, loss of consciousness in air deprived of oxygen is quicker than in drowning; not only is the supply of oxygen cut off, but oxygen in the lungs is rapidly used up; loss of consciousness is followed by convulsions, then by cessation of respiration. The oxygen content may be so depleted that life is in peril before one realizes the danger.

Some of the causes of oxygen deficiency underground are: absorption by water or certain types of rock, ore or fill; the breathing of men in confined spaces; displacement by methane, carbon monoxide or other gases; heating conditions or combustion. The volume of oxygen in mine air should be at least 19.5 per cent.

Carbon Monoxide (CO)

Carbon monoxide is considered to be one of the greatest gas hazards in underground mining. It is one of the products of combustion in blasting operations, from the operation of diesel vehicles, and also produced by such abnormal occurrences as mine fires or gas explosions. It is a product of incomplete

combustion and is produced wherever organic compounds are burned in an atmosphere with insufficient oxygen to carry the process of burning or oxidation to completion. Carbon monoxide is a colourless, odourless, tasteless gas which, when breathed in very low concentrations will produce symptoms of poisoning. Carbon monoxide will burn, and air that contains 12.5 to 74 per cent of carbon monoxide will explode if ignited. It is only slightly soluble in water and is not removed from the air to any extent by water sprays. It is slightly lighter than air, having a specific gravity of 0.967.

Carbon monoxide in excess of 0.005 per cent (50 ppm.) when breathed indefinitely may eventually produce symptoms of poisoning; 0.02 per cent, (200 ppm.) may produce slight symptoms after 1.5 hours exposure. When 0.04 per cent (400 ppm.) is present and the exposure is for two or three hours, headache and discomfort usually occurs. In concentrations of 0.15 to 0.20 per cent, (1,500 to 2,000 ppm.), unconsciousness usually occurs in about 30 minutes.

The effect of high concentrations may be so sudden that one has little or no warning before collapsing.

How Carbon Monoxide Acts

The oxygen absorbed from the air in the lungs is normally taken up by the blood in the form of a loose chemical combination with the red colouring matter (haemoglobin) of the corpuscles, and in this form it is carried to the tissues where it is used. Haemoglobin forms a much more stable compound with carbon monoxide than with oxygen.

The affinity of haemoglobin for carbon monoxide is about 300 times its affinity for oxygen; hence, when even a small percentage of carbon monoxide is present in the air breathed, the haemoglobin will absorb the carbon monoxide in preference to the oxygen. When carbon monoxide is absorbed by haemoglo-

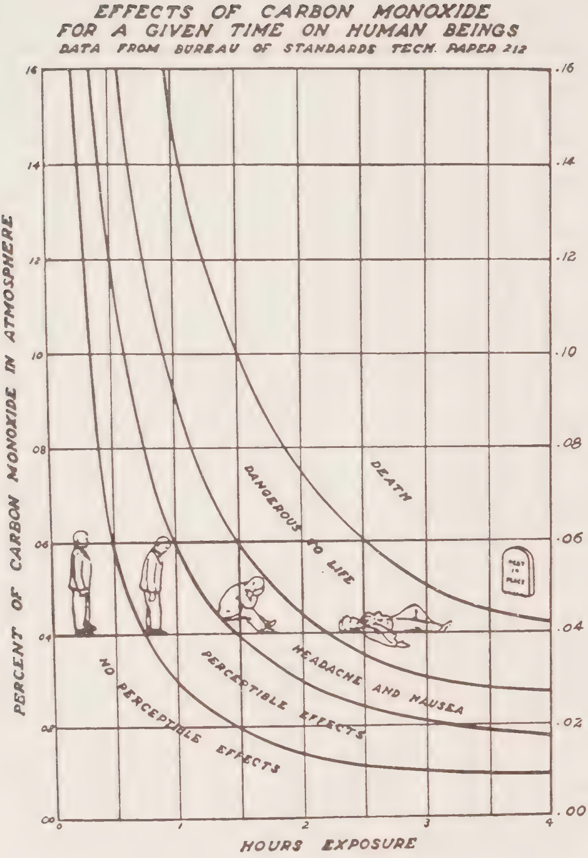


Fig. 9 — Chart Showing Effects of Carbon Monoxide.

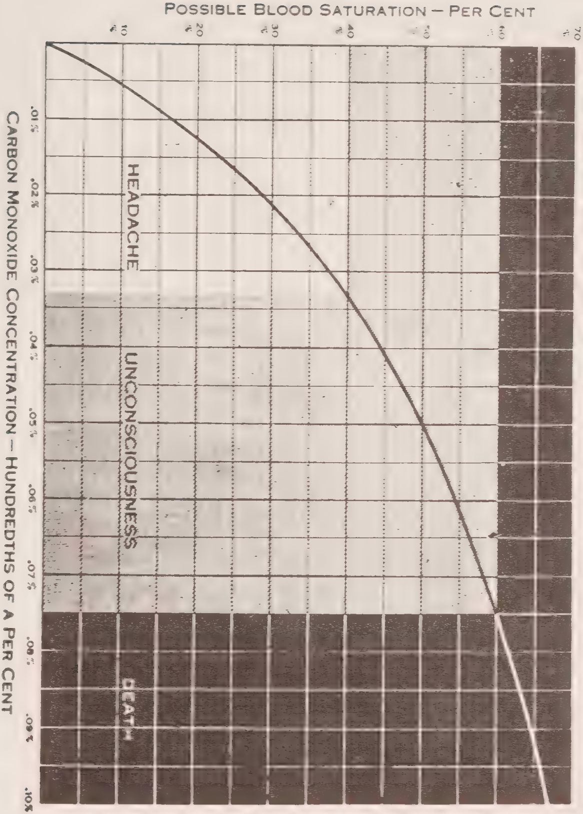


Fig. 10 — Chart Showing Blood Saturations Corresponding to Various Concentrations of Carbon Monoxide.

bin it reduces the capacity of the haemoglobin for carrying oxygen to the tissues to a proportionate extent. It is this interference with the oxygen supply to the tissues that produces the symptoms of poisoning.

The symptoms of poisoning more or less parallel the extent of blood saturation. The first definite symptoms, during rest, make their appearance when 20 to 30 per cent of the haemoglobin is combined with carbon monoxide. Unconsciousness takes place at about 50 per cent saturation, and death occurs at about 80 per cent *(Fig. 10)*.

According to experiments conducted by the U.S. Bureau of Mines, the symptoms produced by various percentages of carbon monoxide in the blood are as follows:

The symptoms decrease in number with the increase in the rate of saturation. If exposed to high concentrations, the victim may experience few symptoms. The rate at which a man is overcome and the sequence in which the symptoms appear depend on several factors: the concentration of gas, the extent to which he is exerting himself, the state of his health and individual susceptibility, and the temperature, humidity and air movement to which he is exposed. Exercise, high temperature and humidity, with little or no air movement, tend to increase respiration and heart rate and consequently result in more rapid absorption of carbon monoxide.

Percentage of Blood Saturation	Symptoms
0-10	None
10-20	Tightness across forehead, possibly headache
20-30	Headache, throbbing in temples
30-40	Severe headache, weakness, dizziness, dimness of vision, nausea, vomiting, and collapse
40-50	Same as 30-40, with more possibility of fainting and collapse, increased pulse and respiration
50-60	Fainting, increased pulse and respiration, coma with intermittent convulsions
60-70	Coma with intermittent convulsions, depressed heart action and respiration, possibly death
70-80	Weak pulse and slowed respiration, respiratory failure and death

Treatment for Carbon Monoxide Poisoning

The onset of carbon monoxide poisoning may be either sudden or gradual, depending on the concentration and period of exposure. Interest usually centres in the treatment of the acute form.

In the general treatment for carbon monoxide poisoning the most important factors are avoiding further exposure and keeping the patient at rest. When a person is suffering from acute poisoning it is important that carbon monoxide be eliminated from the blood stream as quickly as possible, thus decreasing the possibility of serious after effects, including loss of life. As soon as the patient begins to breathe air in which there is no carbon monoxide the process of eliminating the gas from the blood will begin naturally. However, this normal, unaided elimination is slow and often has serious effects. It requires

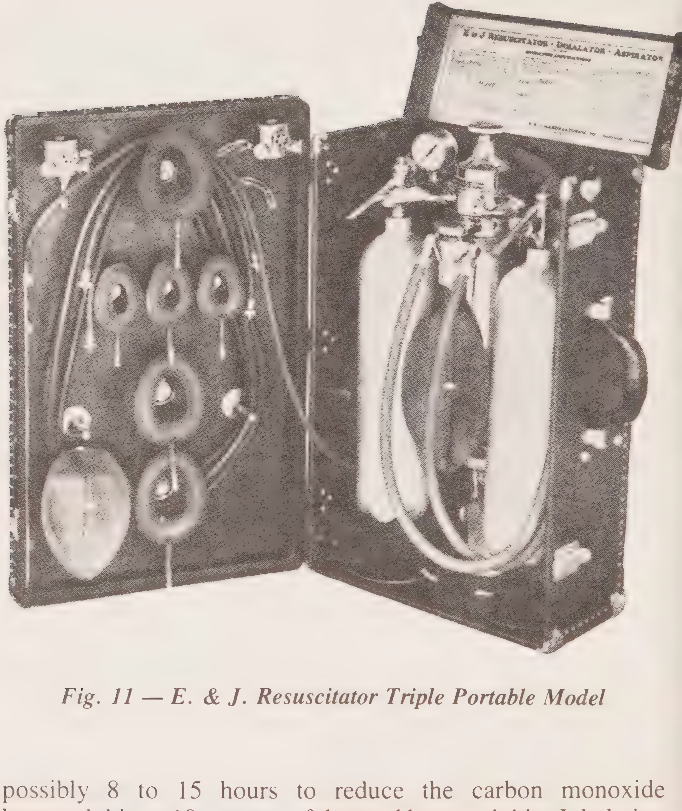


Fig. 11 — E. & J. Resuscitator Triple Portable Model

possibly 8 to 15 hours to reduce the carbon monoxide haemoglobin to 10 per cent of the total haemoglobin. Inhalation of pure oxygen will remove the carbon monoxide from the blood four or five times faster. The use of oxygen alone in an inhalator is common practice because it is usually readily available owing

to its general use in industry. Inhalation treatments are preferably given with an inhalator but the oxygen may be administered by improvised apparatus or sprayed directly over the patient's face from a cylinder when an inhalator is not at hand. Caution should be observed in controlling the flow when using the gas directly from the cylinder. The cylinder should be opened and the flow regulated before the gas is directed toward the patient. No improvised mask or device should be used in which pressure can build up and injure the patient. Because of its great efficiency an inhalator is preferable to any improvised device.

The steps in the effective treatment of carbon monoxide poisoning are as follows:

1. The patient should be removed to fresh air as soon as possible.
2. If breathing has stopped, is weak and intermittent, or is present only in occasional gasps, artificial respiration should be given continuously and persistently until normal breathing is resumed, or until it is definitely established that the patient is dead.
3. Pure oxygen should be administered at atmospheric pressure, beginning as soon as possible and continuing as long as necessary* at least 20 minutes in mild cases and as long as 1 or 2 hours in severe cases.
4. Keep the patient warm with blankets.
5. The patient should be kept at rest, lying down to avoid strain on the heart; later he should be given plenty of time to rest and recuperate.

**It cannot be emphasized too strongly that immediate inhalation of oxygen for 20 to 30 minutes will diminish the severity of carbon monoxide poisoning and decrease the possible serious after effects.*

Artificial Respiration Using an Oxygen Inhalator

"Oxygen Inhalator" is a general term used to designate the apparatus. Several portable types are in use under different trade names. *(Fig. 11)*. They may be classed under two headings, those which act as inhalators only, with manual artificial respiration used if necessary. The second type, known as a resuscitator gives an effect of artificial respiration by mechanical control of the oxygen bottle pressure. The latter type may usually be used as an inhalator if resuscitation is not required.

Carbon Dioxide (CO_2)

Carbon dioxide is a product of the decomposition and/or combustion of organic compounds in the presence of oxygen, and also of the respiration of men and animals. It is a colourless, odourless gas which, when breathed in large quantities, may have a distinct acid taste. It will neither burn nor support combustion. Carbon dioxide, being heavier than air, is often found in low places and abandoned mine workings, and is a normal constituent of mine air. The proportion of carbon dioxide in mine air is increased by the process of breathing, by the burning of flame lamps, by fires, explosions and blasting.

The following table shows the effect upon a human being of increasing amounts of CO_2 in the air breathed:

Percentage of CO_2 in Atmosphere	Increase in Respiration
0.5%	— slight
2.0%	— 50%
3.0%	— 100%
5.0%	— 300% and laborious
10.0%	— Cannot be endured for more than a few minutes.

Carbon dioxide in air has these effects when the oxygen content remains approximately normal and the individual is at rest. Moving around or working increases the effects and the danger is greater than when the individual is resting. Concentrations of over 5 per cent of carbon dioxide in the air are usually accompanied by an appreciable lowering of the oxygen content.

Hydrogen Sulphide (H_2S)

Hydrogen sulphide is one of the most poisonous gases known. Fortunately only traces of it are ordinarily found on rare occasions in Ontario mines. In low concentrations its distinctive "rotten egg" odour is noticeable, but in high concentrations the sense of smell is quickly paralysed by the action of the gas and cannot be relied on for warning. The gas has a specific gravity of 1.19 and, being heavier than air, may collect at low points. A mixture of 4.3 to 46 per cent of hydrogen sulphide in air is explosive. Hydrogen sulphide may also indicate the presence of methane.

Hydrogen sulphide inhaled in a sufficiently high concentration produces immediate asphyxiation; in low concentrations it produces inflammation of the eyes and respiratory tract and sometimes leads to bronchitis and pneumonia.

Sub-acute poisoning may be produced by long exposure to concentrations as low as 50 ppm. Immediate collapse usually results from exposure to concentrations of 0.06 to 0.1 per cent (600 to 1000 ppm.) and death quickly ensues.

When explosions of dust occur in blasting operations in sulphide orebodies, the resulting gases may contain varying amounts of hydrogen sulphide, along with sulphur dioxide and possibly other sulphur gases.

Methane (CH_4)

Methane is a colourless, odourless, tasteless gas. An odour caused by the presence of other gases such as hydrogen

sulphide, may accompany it. Methane will burn with a pale blue non-luminous flame. Air that contains 5 to 15 per cent of methane and 12 per cent or more of oxygen will explode and this is its chief danger. However, the flammable and explosive range of methane is variable and all occurrences of the gas should be considered as dangerous. Where the occurrence of methane is suspected or known, adequate ventilation to dilute the gas to a harmless percentage is important.

Methane or "marsh gas" is encountered in most metal mining districts of Ontario. Flows of the gas are of variable duration according to the size of the pocket tapped. It is formed by the decomposition of organic matter in the presence of water and the absence of air or oxygen. It can be seen in the form of bubbles in stagnant pools, hence the name "marsh gas".

Methane is considerably lighter than air and when found in mines is usually near the roof or higher elevations. Accumulations of the gas may be encountered issuing from diamond drill holes, in unused and poorly ventilated mine workings, or when old workings are being dewatered. It may be caused by the decaying of old timbers.

Methane has no direct effect upon men, but it may displace the oxygen content of the air to such an extent as to cause oxygen deficiency. An open flame lamp or a spark may cause an explosion.

Oxides of Nitrogen

Oxides of nitrogen are formed in mines by the burning and detonation of explosives. They can usually be detected by a "burnt powder" odour and by the reddish colour of nitrogen dioxide fumes, which are formed when the nitric oxide produced by the explosion comes in contact with the air. Hall and Howell report that gases collected from the burning of 40 per cent gelatin dynamite contained 11.9 per cent of oxides of nitrogen. When explosives having properly proportioned

components are completely detonated they usually produce exceedingly small percentages of oxides of nitrogen, which are considered harmless. Explosives from which the wrapper has been removed may produce harmful percentages of oxides of nitrogen, even when detonated.

Oxides of nitrogen corrode the respiratory passages, and the breathing of relatively small quantities may cause death. The effect is unlike that of carbon monoxide in that a person may apparently recover and then suddenly die several days later. Nitrogen dioxide is probably the most irritating of the oxides of nitrogen. Its effects on the respiratory passages usually are not manifest until several hours after exposure, when oedema and swelling take place. This irritation may be followed by bronchitis or pneumonia, frequently with fatal results. One hundred parts per million of nitrogen dioxide may cause severe illness if breathed for a short time.

The present maximum allowable concentration for exposure to nitrogen dioxide is 5 ppm.

Oxides of nitrogen are also a component of diesel engine exhausts.

Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas. It is a suffocating, irritating gas with the familiar pungent, sulphurous odour. It is sometimes given off by the detonation of explosives and is present at the time of mine fires in sulphide orebodies.

Sulphur dioxide is very poisonous, but, owing to its irritating effect on the eyes and respiratory passages, is intolerable to breathe for any length of time.

Nitrogen (N_2)

Nitrogen is an inert gas, it is colourless, odourless, tasteless and a chief constituent of the atmosphere. It is not combustible, nor will it support combustion. It has no physiological effect on man

and is only dangerous if it has displaced the oxygen content below a safe limit. Higher than normal nitrogen mixtures may be encountered where the oxygen content has been consumed by the oxidation of various substances, supporting of an active fire or the oxygen being consumed by water in confined areas. The oxygen may be reduced to a very low point and the mine atmosphere may also contain the products of combustion such as carbon dioxide, carbon monoxide and sulphur dioxide.

Hydrogen (H_2)

Hydrogen is a colourless, odourless tasteless gas. It is not dangerous to breathe, but is combustible and is dangerous because of its explosiveness (4.1 to 74 per cent in air). In addition to this, at the time of a mine fire it may unite with carbon to form explosive concentrations of hydrocarbons.

The gas is found in normal air in very small quantities. It is sometimes found in the mine atmosphere during or after a fire, particularly when the rocks have been heated to incandescence. It is also a product of the electrolytic action in the charging of batteries used in mine locomotives.

Smoke

Smoke consists of exceedingly fine particles of solid and liquid matter suspended in the atmosphere. These particles are composed mostly of soot or carbon, together with tarry substances, mainly hydrocarbons. Asphyxiating and irritating gases and vapours are usually mixed with the smoke. Hydrocarbons in sufficient concentration may be explosive.

The Damps

The word "damp" is a derivation of the German word "dampf" which means "vapours or gases". The term "damp" was used by the early miners to describe the mixtures of gases or their

effect on persons. Although not normally used in metal mining the terms are common in coal mining.

Firedamp

''Firedamp'' is the term describing a mixture of methane and air, that will burn or explode when ignited. The ''fire'' in fire damp comes from the fact that the mixture is flammable.

Afterdamp

''Afterdamp'' is a product of a mine fire or explosion. It consists mainly of carbon monoxide, carbon dioxide, low oxygen and high nitrogen.

Blackdamp

J. S. Haldane defines ''blackdamp'' as an accumulation of carbon dioxide and nitrogen in proportions larger than those found in normal air. It is found in abandoned workings or sealed areas, and in wells. Blackdamp may also be formed by mine fires or explosions of firedamp in mines, and in such instances may contain fairly large quantities of carbon monoxide.

Hazards Due to Gases During or After Mine Fires or Explosions

During and following metal mine fires the two greatest hazards to life are poisoning from the breathing of carbon monoxide and suffocation in an atmosphere deficient in oxygen. Conditions which cause contamination in mine atmospheres are:

Carbon monoxide — This gas is always present at the time of an underground fire and gives little or no warning.

Oxygen deficiency — This condition occurs because of the consumption of oxygen by combustion or chemical reaction and its replacement by toxic or inert gases.

Smoke — The hazard is due to its irritating qualities and obstruction of vision. It may be explosive and poisonous, containing the products of the decomposition of synthetic materials due to heat.

Danger of explosion — Hydrocarbon gases caused or generated by fire (as in Smoke) may explode.

Methane — This gas is not produced by mine fires or explosions but may cause them. Its presence may then create a hazard.

Sulphur dioxide — This gas may be present during the mining of sulphide orebodies. Because of its irritating qualities it gives advance warning when in less than toxic concentrations.

Hazards Created By The Burning of Conveyor Belts and Rubber Tires

"The severity of a fire which can spread along a conveyorway has been emphasized by the disaster at Creswell Colliery, Derbyshire, when 80 men were overtaken and killed by poisonous fumes from the fire."

"In fires caused in conveyor belting by frictional heating, the cotton carcase is usually responsible for the ignition, but once the belting is ignited, the rubber cover causes the spread of flame. Materials in addition to the belting, (in metal mines this could be grease and oil) are likely to support the burning of the belt."

"Poly-vinyl-cloride (P.V.C.) covered belting is practically non flammable, but when heated, both P.V.C. and neoprene as is found in rubber tires, give off chlorine gases."

"P.V.C. contains 55% by weight of chlorine. Synthetic rubber, and neoprene contain about 40% of chlorine."

"The products of decomposition and burning of conveyor belting and rubber tires are many and complex. The gases

produced are listed below, and to indicate the danger of some of these gases, the maximum allowable concentrations permitted are shown. Carbon monoxide is actually one of the least poisonous.''

Gases Produced by Burning Rubber, Neoprene and P.V.C.	Maximum Allowable Concentration	
	P.P.M.	**Per Cent**
Carbon Monoxide	50	0.005
Chlorine	1	0.0001
Hydrogen Chloride	5	0.0005
***Phosgene**	0.1	0.00001
Sulphur Dioxide	5	0.0005
Hydrogen Sulphide	10	0.001
Nitrogen Dioxide	5	0.0005
Ammonia	50	0.005
Hydrogen Cyanide	10	0.001
***Arsine**	0.05	0.000005
***Phosphine**	0.3	0.00003

''The last two gases will be found only if the carcase is impregnated with certain fungicidal or fire retardant compositions.''

The information has been taken from the publication ''Investigations into Underground Fires'' by the Safety in Mines Research Establishment, Buxton, England.

**Note the toxicity of these gases as compared to carbon monoxide.*

Important Characteristics of Mine Gases

The important characteristics of mine gases are set out in the two following tables:

Gas	Sol. in* H_2O	Explosive	Explosive Range Per Cent	Combustible	Colour	Odour	Taste	Dangerous to Breathe
Air	.019	No	—	No	None	None	None	No
Oxygen	.031	No	—	No	None	None	None	No
Carbon dioxide	.878	No	—	No	None	None	None	Yes[1]
Methane	.033	Yes	5.0 to 15	Yes	None	None	None	No[2]
Carbon monoxide	.023	Yes	1.25 to 74	Yes	None	None	None	Yes[3]
Hydrogen sulphide	2.672	Yes	4.3 to 46	Yes	None	Yes	Yes	Yes[3]
Nitrogen dioxide	—	No	—	No	Red	None	Yes	Yes[3]
Sulphur dioxide	—	No	—	No	None	Yes	Yes	Yes[3]
Hydrogen	.018	Yes	4.1 to 74	Yes	None	None	None	No
Nitrogen	.016	No	—	No	None	None	None	No
Gasoline (for comparison)	.21	Yes	1 to 6%	Yes	None	Yes	Yes	Yes[3]

[1] In fairly high concentrations, above 5% or more.

[2] Sometimes accomplished by H_2S.

[3] Extremely dangerous even in very low concentrations.

*C.C. of gas absorbed per c.c. of water at 20°C or 68°F at atmos pressure.

Gas	Formula	Molecular Weight	Weight at 0°C and 760 mm. Hg. Grams per Litre	Weight at 0°C and 760 mm. Hg. Pounds per Cubic Foot	Specific Gravity, Air=1
Air	—	—	1.2928	0.08067	1.0000
Oxygen	O_2	32.00	1.4291	0.08918	1.1054
Carbon dioxide	CO_2	44.00	1.9768	0.12335	1.5291
Methane	CH_4	16.03	0.7168	0.04473	0.5545
Carbon monoxide	CO	28.00	1.2504	0.07805	0.9672
Hydrogen sulphide	H_2S	34.09	1.5392	0.09605	1.1906
Nitrogen dioxide	NO_2	46.01	2.0548	0.12822	1.5894
Sulphur dioxide	SO_2	64.07	2.9266	0.18262	2 2638
Hydrogen	H_2	2.01	0.0899	0.00561	0.0695
Nitrogen	N_2	28.02	1.2507	0.07804	0.9674

Questions on Chapter II

1 What are the main components of air and in what percentages do they occur?

2 Give the characteristics of oxygen.

3 Will oxygen burn or explode if it is pure?

4 What gases are we most likely to encounter in a fire in a mine?

5 (a) Name and describe the most deadly gas encountered during mine fires or explosions.
(b) At about what percentage in air does this gas become dangerous to breathe?
(c) What first aid treatment is recommended for persons affected by this gas?

6 What other gases may be found in a mine fire in sulphide orebodies?

7 What gas or gases are usually associated with blasting?

8 What gases are usually present with smoke?

9 What explosive gases, if any, are we likely to find in mine air?

10 Name some of the causes of deficiency of oxygen in air.

11 What colour is the face when the oxygen content of the air is low?

12 What difference is there in the symptoms of oxygen deficiency between air at sea level that has a low oxygen content and the atmosphere at 1,700 metres.

13 When a person succumbs to oxygen deficiency does respiration or the hearbeat stop first?

14 Without the use of special instruments is there any way we can detect the presence of certain gases?

15 (a) With what gas do we associate the smell of rotten eggs?

(b) In a very small concentration of this gas what are the first noticeable symptoms?

16 Does breathing pure oxygen at atmospheric pressures have any adverse effect on men?

17 What are considered the two greatest hazards to men during mine fires with regard to mine air?

18 What are the symptoms of carbon monoxide poisoning?

Chapter III

Methods of Detection of Mine Gases

Various methods and devices are in use for detecting certain toxic, noxious and explosive gases in mine air. The presence of carbon monoxide and deficiency of oxygen are the greatest hazards encountered during mine rescue or recovery operations and there are accurate and speedy means of detecting them. Hydrogen sulphide and sulphur dioxide may be detected by the sense of smell before they are present in dangerous quantities.

Carbon Monoxide Detectors

Several rapid and sufficiently accurate methods of detection of carbon monoxide are in common use.

1. The Drager Gas Detector
2. The Gastec Gas Detector
3. Electronic Sensing Devices

Drager Gas Detector

This instrument, *(Fig. 12)* consists of a spring-loaded rubber bellows with a capacity of 100 cubic centimetres of air, and a replaceable indicating tube. Air to be tested is drawn directly into the indicating tube before passing into the bellows, and thus the instrument requires no purging before inserting the tube.

The outlet valve of the bellows provides very little resistance for the release of the gas sample, eliminating the need for an inlet valve.

The Drager Gas Detector is designed for the testing of a number of gases, using various indicating tubes. We are

Fig. 12 —
Drager Gas Detector

Fig. 13 —
Gastec Gas Detector

concerned here primarily with the testing for carbon monoxide.

Several types of indicating tubes are available for testing of low and high concentrations of carbon monoxide. The detector tube carried by the teams is the 10/b low range tube, which is capable of testing the air for carbon monoxide in the range of 10 to 3,000 ppm. All tubes contain filtering chemicals to remove hydrocarbons and other gases that could affect the reading of the instruments.

Inspecting the Detector Before Use

The bellows should be squeezed once or twice to be sure the outlet valve is operating. Insert an unbroken indicating tube into the inlet and collapse the bellows. The bellows should remain collapsed unless the outlet valve is leaking. It is not necessary to check the time taken for the bellows to inflate, as that action is controlled by the resistance built into each indicating tube. If the outlet valve is leaking, the valve cover plate may be removed and the valve seat inspected and cleaned.

Field Test by Team Members

1. Examine the tester for damage, deterioration, etc.
2. Squeeze the bellows once or twice to be sure it is working.
3. Insert an unbroken tube into the inlet and collapse the bellows.
4. Observe the bellows for expansion, indicating a leak.
5. Check the indicating tubes to assure a sufficient supply.
6. Report the results to the team captain.

Use of the Detector

To use the detector, select the proper CO indicating tube, depending on the concentration of CO that may be expected due to conditions that are known. Break the sealed ends of the

indicating tube by inserting them in the "breaker" at one end of the drag chain on the bellows. Insert the tube firmly into the detector inlet so the passage of air will be according to the arrow on the tube, squeeze the bellows fully to expel the residual air, and then allow the bellows to refill completely. If the air sampled contains carbon monoxide, a dark stain will be noticed extending downwards through the white crystals. The concentration is measured according to the distance the stain extends into the crystals.

When a one squeeze test has been made, the N-1 scale on the tube comprised of the figures 100, 500, 1,000, 2,000, 3,000 are direct readings in parts per million.

If the colour change is too slight to be readily observed after one squeeze or does not extend as far as the first marking, nine more squeezes should be given. The reading is then taken on the N-10 scale comprised of the figures 10, 50, 100, 200, 300 and are also direct readings in parts per million.

The reading is taken at the lowest level of the general discoloration, and NOT at the deepest point of colour penetration.

All tubes have a band on the upper end on which can be written data concerning the test. Tubes, once coloured when capped, will not change colour for several hours, and so may be read later under better lighting conditions than found in testing areas underground. Tubes that have been used, may be reused up to 10 times within a 24-hour period when no colour reaction is obtained. Once coloured, they must not be reused.

Only Drager tubes are to be used with the Drager Gas Detector as any other tube would give a false reading.

Gastec Gas Detector

Sampling Pump

1. Gastec design does not require flowrate orifices.
2. Handle locks at precise intake volume of 50 or 100 cc.
3. Lubricant seal packing provides complete leakproof sampling at all times.

Detector Tube

1. Direct reading calibration scale printed on each tube.
2. Small internal diameter of tubes provide long stain length with one stroke of the pump (100 ml).
3. Sensitive reagents with high reaction rates provide a clear line of colour stain.

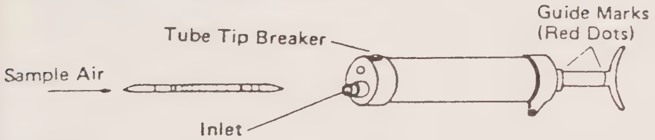
Principle of Gastec Detector Tube

Each detector tube contains a precise amount of detecting reagants and is hermetically sealed at both ends.

To operate, break tips off a fresh tube and connect the tube to the Gastec sampling pump and pull handle to take the required sample of air. The chemical reagents in the detector tube will then react with the sampled gas immediately and colour stain will develop starting at the inlet of the detector tube. The gas concentration is measured at the interface of stained-to-unstained reagent when reaction stops.

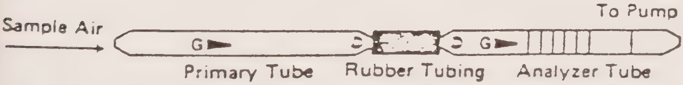
Gastec detector tubes contain colorimetric reagents. The reagents are sensitive to particular gases or vapours and react to provide a length-of-stain indication.

Operating Procedure for Gastec Precision Gas Detector System



Sampling and Measurement Procedure

1. Break tips off a fresh detector tube by inserting the ends in the tube tip breaker of the pump.
2. Insert tube securely into pump inlet with arrow on tube pointing toward pump.
3. For twin tubes, connect (c) marked ends with rubber tubing after breaking each end. Insert analyzer tube into pump with arrows on tubes pointing toward pump. See Figure below.



4. Make certain pump handle is all the way in. Align red dots on pump body and handle.
5. Pull handle out to desired stroke volume. Handle can be locked on either 1/2 pump stroke (50 cc) or one pump stroke (100 cc).
6. Read concentration at the interface of stained-to-unstained reagent when staining stops. Unlock handle by making 1/4 turn and return it to starting position.
7. If no reading is obtained, additional pump strokes may be given using the same tube.

MX 240 Dual Monitor

The MX 240 dual-sensor instrument is designed for use in mines to warn against both oxygen (O_2) deficiency and hazardous levels of methane (CH_4).

The oxygen level is indicated continually on a digital liquid crystal display (LCD.). Methane readouts on the LCD. are obtained by pressing a sealed switch on the side of the unit. The O_2 readings range from 0 to 100 per cent in 0.1 per cent increments.

Methane is measured by a catalytic sensor which provides measurements ranging from 0 to 3.0 per cent in increments of 0.1 per cent methane. With modifications it will indicate up to 5.0 per cent methane.

The MX240 features an on-off switch that prevents accidental shutoff during a sampling period. If the oxygen level falls below a preset limit or the methane level rises above the preset limit, a built in audible alarm is activated. The alarm also sounds to indicate a low battery charge or a malfunction in either sensor element which would prevent accurate gas measurements.

Charging

A basic requirement is an AC battery charger. These can be supplied in single or five-unit models that operate on 120 V, 50/60 Hz or 230 V, 50/60 Hz. A 12-Volt DC single unit charger also is available. All chargers produce a true constant current to prevent overcharging the instrument's replaceable nickel cadmium battery pack.

The battery operated SP 200 Sampling Pump is supplied with a 10-foot length of flexible tubing and permits the MX 240 to sample air in remote or confined areas. In high noise work environments, the AD 200 Audio Driver can be used to transmit the audible alarm signal electronically to an earphone or a headset.

Specifications

Dimensions:	4.75 x 2.75 x 1.5 inches (121 x 70 x 38 mm)
Weight:	18.8 ounces (532 g)
Sensors:	Oxygen: Temperature-compensated galvanic electrochemical cell Methane: Catalytic bead
Readouts:	Liquid crystal display: O_2 range: 0-100% in 0.1% increments Liquid crystal display: CH_4 range: 0-3.0% in 0.1% increments
Operating Time:	9+ hours (with fully-charged battery)
Temperature Range:	32 to 112°F (0 to 45°C)
Power Source:	Intrinsically safe nickel-cadmium battery pack
Recharging Time:	14 hours for full recharge
Calibration:	All adjustments accessible from outside of case.

Model 922 Combustible Gas/Oxygen Analyzer

Operating Instructions

Warning: The instrument should not be used to measure combustible gas in atmospheres either oxygen deficient or containing more than 25 per cent oxygen by volume, unless proper protection is worn.

General: The BioMarine Combustible Gas/Oxygen Detector provides a simple method of determining oxygen concentrations and combustible gas levels in any environment. The meter

continuously displays oxygen concentrations with no battery drain. Over 200 combustible gas measurements may be taken before battery recharging.

The detector operates automatically at full range. The

Fig. 14 — Model 922 Combustible Gas/Oxygen Analyzer

detector requires infrequent calibration and performs accurately in high humidity environments. While methane is the calibration standard for the combustible gas detector, other combustible gases will be detected. If desired, combustible gases other than methane may be used for calibration.

Principle of Operation

Oxygen Sensor

Oxygen is sensed directly by an internal galvanic cell containing a gold cathode and a lead anode in a basic electrolyte. The entire cell is enclosed in plastic. Oxygen diffusing through the cell face initiates reactions which generate a minute current proportional to the oxygen concentration. A temperature compensated circuit converts the current to a proportional voltage which is displayed directly on the meter face of the analyzer as oxygen concentration. No battery power is required for oxygen measurement.

Combustible Gas Sensor

The combustible gas sensor is a coil of platinum wire coated with a ceramic bead and treated with a catalyst. When the detecting element is heated, it causes the combustible gas to burn, raising the temperature of the coated platinum wire. The resistance of the platinum wire is dependent upon its temperature. Therefore, by using a Wheatstone bridge detecting circuit, the change in bead temperature, caused by burning gas, is transformed into an electrical signal displayed on the meter. Normally, about 200 combustible gas readings may be taken before recharging the battery.

Cautions

1. The battery must be tested before each combustible gas measurement. Never make a combustible gas measurement

if the battery test indication is below the green battery band. Erroneous readings will result.

2. In combustible gas concentrations above lower explosive limit (LEL), the instrument will give incorrect readings. If it is suspected that concentrations higher than the LEL are present, instruments capable of measuring these high levels should be used.

3. Tetraethyl lead or compounds containing silicon (sometimes used as lubricants or hydraulic fluids) may poison the detector and prevent accurate readings. When the presence of these materials is suspected, test the calibration of the unit daily.

Operating Instructions

Oxygen Measurement

1. The meter continuously displays the oxygen concentration unless measuring combustible gas.

2. Oxygen reading in fresh air should be 21 per cent; if not, adjust the oxygen calibration screw until 21 per cent reading is obtained.

Combustible Gas Measurement

1. Test battery charge by depressing "battery test" button. Meter should indicate within the green band. If a low reading is obtained, the battery must be recharged.

2. **Zero Test:** With the unit exposed to combustible gas-free environment, depress the sample button. Check that the reading obtained is within the black band. If the steady (10-second) reading deviates from this band, the zero must be adjusted.

3. Depress and hold the sample button for 10 seconds or until highest steady combustible gas reading is obtained. Take the reading on the lower meter scale, calibrated in 0-100 per cent LEL.

4. Wait at least 30 seconds before repeating operation.

Battery Charging

1. Raise the spring-loaded battery jack cover and insert the plug of the battery charger.

2. Plug the charger module into a 115V 50 or 60 Hz socket.

3. Charge the battery for 8 to 16 hours.

Caution: Overcharging the battery may lead to a decrease in its life. Do not leave the charger connected for over sixteen (16) hours.

Preventive Maintenance

It is advisable to perform the following operation on a routine basis. Check and adjust the calibration of the instrument once a month if used under normal conditions, and every 72 hours if used in extreme temperature and humidity atmospheres.

Methane Detectors

The flame safety lamp has been the standard means used for detection of methane in the past and can be used for the detection and determination of methane gas in air within a range of 1.0 to 4.0 per cent. However, a thoroughly trained and experienced operator is required to obtain an accurate determination of methane by this method. Electrical thermo-coupled detectors are now replacing the flame safety lamp in Ontario mines. The method of testing for methane with the flame safety lamp is described later in the text.

Fig. 15 — G-70 Methanometer

The G-70 Methanometer

The G-70 methanometer is a hand held, electrically operated instrument, used to detect and accurately measure the amount of methane gas present in the atmosphere of the mine in a range of 0 to 5 per cent. An excess of 5 per cent will be indicated but without accuracy.

The instrument operates according to the principles of the Wheatstone bridge circuit in which an air sample is drawn through the instrument and the combustible content of the air is burned on a wire element. This element is one leg of the Wheatstone bridge circuit. As the temperature of the detector element increases, the electrical resistance will also increase and

the Wheatstone bridge circuit becomes unbalanced.

The degree of change in the electrical circuit is indicated by a meter. The meter gives a reading which is equivalent to the concentration of methane gas in the air that is being tested.

The G-70 methanometer is powered by one rechargeable cell, the capacity of which is adequate for approximately 300 measurements of 10 to 12 seconds in duration. The voltage indicator of this cell is situated in the upper right hand corner on the front of the instrument, and will show the state of charge during each operation.

When the cell is fully discharged the pointer remains on the red area of the indicator when a test is being made. For proper testing, the pointer must remain in the white area during the test, indicating a fully charged cell.

A portable battery charger is provided for the G-70 methanometer and charging time is approximately 10 hours.

The instrument may also be fitted with telescopic sampling probes of different lengths to facilitate probe sampling in difficult locations.

Preparing the Tester for Use

1. First check the zero setting by visual observation of the needle when the instrument is not energized.

2. Next the cell charge and the electrical zero are checked simultaneously:
   (a) Depress and continue to hold either range button "2" or "5". You will hear a buzzing sound which indicates that the pump is activated and a sample of air is being drawn into the instrument. When the pump action stops, the needle will deflect to the left and then return to the right which indicates that the instrument is in proper working order. If the needle comes to rest at any point other than zero an adjustment must be made.

(b) While continuing to hold the range button depressed, observe the red and white coloured voltage indicator. If the pointer remains in the red area it indicates low voltage and the instrument cannot be used to detect methane until it has been recharged. If the pointer remains in the middle of the white area it indicates optimum working voltage and is suitable for use.

Test for Methane

The dial shows two measuring scales, the upper scale is graduated for measuring from 0 to 2 per cent methane and the bottom scale ranges from 1.8 to 5 per cent.

To make the test, depress the desired range button "2" (for upper scale reading) or "5" (for bottom scale reading). The operation of the suction pump will be heard, which is automatically controlled. Hold the selected range button in the depressed position during the entire operation. The needle will deflect first to the left and then return to the right, coming to rest on the dial and indicating the methane concentration.

Ranges exceeding 0 to 5 per cent can be indicated on the G-70 methanometer and would be indicated by what appears to be an abnormal or erratic behaviour of the needle.

When ranges are in the 5-15 per cent range, with range button "5" depressed, the needle will deflect quickly from the zero point to the right, passing off the scale until it comes to rest at the dial stop. The pointer will rest at the stop for 2 to 12 seconds, depending upon the concentration of methane, and then return to a point left of the zero point.

The higher the concentration of methane the shorter the time for the return of the needle to the left of the zero point.

When the measurement is in the 15 to 60 per cent range, with range button "5" depressed the needle will deflect only partly to the right and will return immediately to the left of the zero point,

where it will remain until the range button has been released.

When the measurement is in the 60 to 100 per cent range, with range button "5" depressed, and upon expiration of the pump operation time, the needle will deflect very quickly from the zero point to the left of zero where it will remain until the range button has been released.

Flame Safety Lamp

Prior to the advent of electronic methane detectors the percentage of methane in an atmosphere was determined by testing with a flame safety lamp.

Origin of the Flame Safety Lamp

One major problem encountered during deeper coal mine development in the early part of the nineteenth century, was the ignition of pockets of methane gas by the flame of the tallow candles used by the miners for illumination. Although it was recognized that the candle must be kept close to the floor of the workings, hopefully out of contact with the lighter than air, methane gas, a thrilling part of the miner's work came when he very slowly raised the candle, one hand shielding the flame. As it was raised an appearance of a "gas cap" of blue flame above the candle flame indicated the presence of gas in the air. This gas was then dispersed by turbulence from the waving of clothing and work would continue. Another method of disposing of the gas accumulation was to set fire to it, usually on night shift by a "fire boss" who would cover himself with wet burlap cloth and slowly raise the lighted candle on the end of a long pole until the pocket of gas was ignited.

The resulting death toll from these early practices in the British coal mines prompted Sir Humphrey Davy, scientist, to research safer ways of determining the presence of gas. In 1815 he was able to announce that a small explosion of fire damp

(methane gas mixture) will not pass through a wire gauze, since the mesh dissipates the heat of the flame quickly and so the basis for the first flame safety lamp, the Davy lamp was developed.

To this day an approved flame safety lamp is widely used as a ready means of an indication for unsafe conditions, even though electronic sensing devices are in common use.

Flame Safety Lamp Testing Cabinet

The testing cabinet is used to demonstrate the reaction that takes place within a flame safety lamp as it is introduced into an area.

1. deficient in oxygen;
2. containing various percentages of methane.
3. It is also used to demonstrate the result of carrying a lamp with defective screens into explosive mixtures of methane.

Uses of the Lamp

The flame safety lamp (Wolf or Koehler) provides a ready method for determining oxygen deficiency, and to indicate the presence of methane.

It must not be used in any place known to contain acetylene, hydrogen, or a known explosive mixture of methane and air.

Electrical methane testers have largely displaced the safety lamp in testing for methane. They are comparatively accurate, safer to operate and require less experience.

The main use of the safety lamp now is in testing for oxygen deficiency. The flame of the lamp will go out if there is less than 16.25 per cent of oxygen by volume in the atmosphere.

The main parts of the lamp are:

1. A fuel reservoir filled with cotton batting and complete with igniter, wick, wick adjuster screw and filler plug.

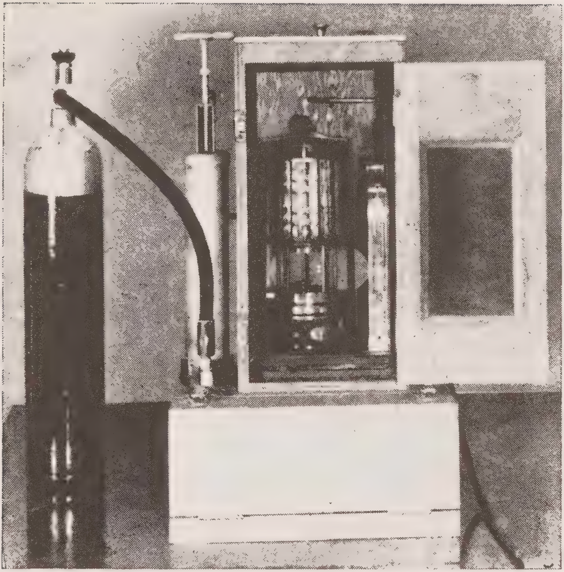


Fig. 16 — Flame Safety Lamp Testing Cabinet

2. Air admission ring containing double inlet screens.
3. Protecting ring (Wolf lamp only).
4. Pyrex glass chimney with asbestos gaskets top and bottom.
5. Flexible ring to allow for expansion of the chimney.
6. Inner and outer fine wire screens.
7. Hood and bonnet assembly.
   The brass lamp weighs about 1.53 kg (3 lb 6 oz) and the aluminum lamp about 1.08 kg (2 lb 6 oz).

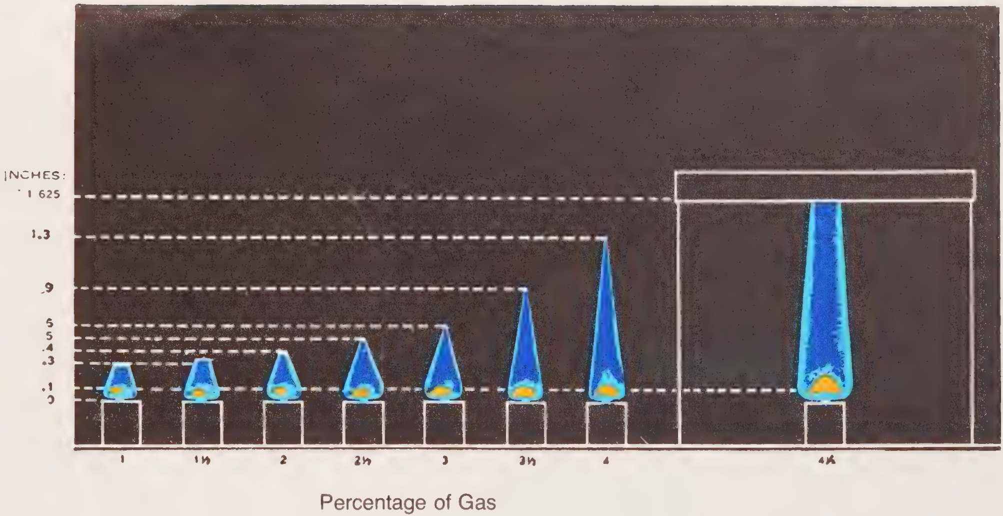


Fig. 17 — Height of Gas Caps with Wolf Round-wick Lamp. Upper Limit of Visible Gas Cap. Total Height of Cap Indeterminate.

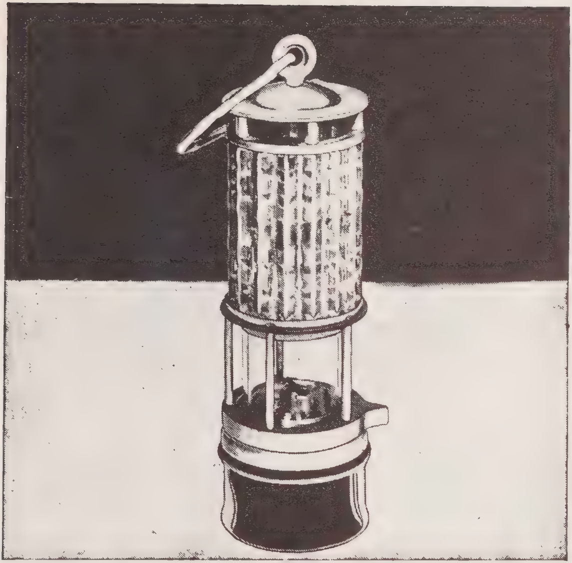


Fig. 18 — Wolf Flame Safety Lamp
Round-wick Type, With Key Lock

Care and Operation of the Lamp

Filling the Lamp With Fuel — Only naptha should be used for fuel in the lamp. Neither benzine nor gasoline should be used.

In filling the lamp only a sufficient amount of fuel to saturate the cotton with which the reservoir is packed should be used. After the lamp has been filled it should be turned upside down so that any excess fuel will drain out. Care should be taken to remove any fuel which may remain on the outside of the lamp after filling. This precaution is necessary, because when the

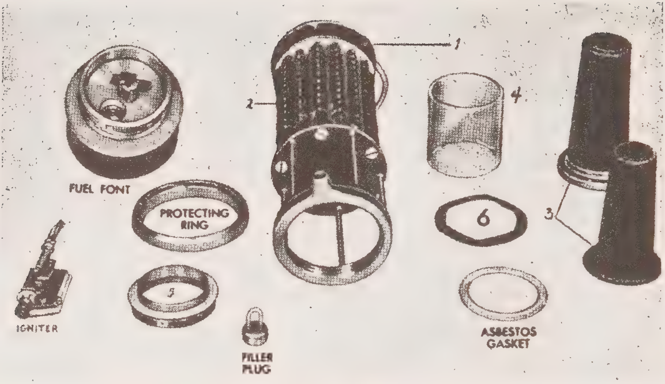


Fig. 19 — Parts of Wolf Flame Safety Lamp

Fig. 20 — Koehler Flame Safety Lamp

lamp becomes heated this excess fuel may evaporate and enter the testing flame, thereby tending to cause false interpretations.

Examining and Cleaning the Wire Screens — The wire screens constitute the safety feature of the lamp. This depends on the cooling effect that a wire screen exerts on flame. Combustible gases ignite at certain fixed temperatures and if the temperature is decreased from any cause the flame is extinguished. Any deterioration of the screens, slight though it may be, is a direct source of danger. It is therefore very important that these be examined carefully for indications of wear or other imperfections. Even though no indication of wear is visible, the screen should not be used for too great a length of time, since the heat of the flame oxidizes the wires, gradually reducing the diameter and decreasing the heat conducting capacity.

The air admission ring of the lamp is also provided with two wire screens, which require careful attention. Although these are not exposed to the heat of the flame, they should be examined carefully to determine whether they are in good condition and are properly connected to the ring. If found to have deteriorated in any way the complete ring should be replaced. For cleaning the screen a wire bristle brush should be used. This brush will thoroughly clean the inside and outside of the screens.

Preparing the Lamp for Testing — Before the lamp is used to make a test it should be carefully examined to ensure that all parts are in good condition, that they fit properly, and that no parts are missing. It is very important that the screens be free from dust, oil, soot, or any other obstruction which will interfere with the air circulation through the lamp. Attention should also be given to the wick. It should be trimmed of excess crust to prevent clogging so that the fuel will feed freely and produce a flame which is stable and uniform.

Fig. 21 — Parts of Koehler Flame Safety Lamp

Assembling the Lamp — Care should be taken to ensure that the lamp has been properly assembled after filling or cleaning. The following are some of the errors likely to occur in assembling the lamp:

1. omitting one of the screens;
2. failing to screw the fuel font into place so as to make a tight fit between the glass chimney and the gaskets;
3. placing a defective screen in the lamp;
4. leaving out one or both chimney gaskets;
5. inserting a chipped or cracked glass chimney;
6. replacing filler plug with an omitted or defective gasket.

Field Test by Team Members

1. Completely strip the lamp, checking the parts.
2. Fill the fuel font, examine the wick and light the lamp.
3. Examine and clean the air admission rings and screens.
4. Reassemble the lamp, checking the condition of the gaskets.
5. Adjust the flame to approximately one half inch.
6. Report results to the team captain.

Testing With the Lamp

In making the tests with the lamp, the following instructions should be observed:

1. Light the lamp about 5 minutes before using for a test so that the flame will reach its normal operating temperature. Adjust the flame so that it will be about 1.3 cm high when burning in a normal atmosphere.
2. If the flame decreases in height and flickers, it indicates that there is a deficiency of oxygen in the atmosphere. Under this condition the flame will be extinguished completely when the oxygen content of the atmosphere is reduced to 16.25 per cent. When a deficiency of oxygen is indicated, the area should be thoroughly ventilated and then retested before general admission is allowed.

As a matter of interest, the following table indicates the decrease of illumination produced by a flame lamp as the percentage of oxygen in the air is decreased. When the percentage of illumination drops below 20 per cent, a slight jar will extinguish the lamp, after which it is almost impossible to relight.

Per Cent of Oxygen	Per Cent of Illumination
20.93	100%
20.30	75%
19.30	40%
18.30	12%
16.25	nil

The Testing Flame — If a safety lamp burning in pure air with a full or slightly lowered flame is introduced into air containing 2.5 to 3.0 per cent of methane, the gas cap may not be seen but the lamp flame will get a little longer, or ''draw'' or ''spire''. In order to test for methane and estimate the percentage, the wick must first be drawn down carefully until the flame is very small. (about 2.5 mm in height) and shows no more than a speck of yellow light.

A low testing flame is essential *(Fig. 17),* because unless the flame is lowered the light from it renders the gas cap invisible. The observer should be thoroughly familiar with the appearance of such a testing flame when the lamp is burning in fresh air, in a main intake airway for example.

The Fuel Cap — The observer will see a continuous pale blue line defining the top of the testing flame, with a speck of yellow light in the middle. Above the blue line will be seen a very faint fuzzy outline of paler blue; this is called the fuel cap. With lamps burning a volatile spirit, such as naptha, the fuel cap may be 2.5 mm (0.1 in.) in height above the top of the testing flame.

The Gas or Methane Cap — When methane is present in the air a gas cap or methane cap, somewhat similar in colour and appearance to the fuel cap, is seen stretching up from the testing flame.

It is not difficult, with practice, to distinguish a gas cap from a fuel cap. Unless they are distinguished, however, mistakes will occur in estimating small percentages of methane.

The illustration *(Fig. 17)* is a reproduction of photographs of the testing flame in a safety lamp which is burning naptha and has a round wick and the air inlets in the middle ring, and of the gas caps as they appear above the testing flame when the air contains different percentages of methane. The reproduction gives a fair idea of the size and shape of the gas caps, but not of their texture and colour, which are something like those of a faint wisp of tobacco smoke. A gas cap might be described as "the ghost of a pale blue flame."

Gas Caps and Percentages — The gas cap is first seen when about 1 per cent of methane is present. It takes the form of a very faint extension or fringe at the extreme edges of the testing flame.

As the percentage of methane increases, the gas cap spreads across the testing flame and becomes larger and clearer, until it forms a complete triangle above the testing flame indicating that 2.5 per cent of methane is present. The triangle gets taller as higher percentages are met with until, at 4 per cent of methane, the gas cap begins to reach to the top of the glass, and as the percentage of methane increases still further, the cap may eventually spire up into the screen chimney.

Precautions

If the gas cap approaches the top of the glass, the lamp should be steadily drawn back into purer air; otherwise a further slight increase in the proportion of methane may cause the mixture within the lamp to explode and put out the testing flame. The cap should not be allowed to spire up into the screen.

Methane should not be allowed to continue to burn inside the screen of a lamp. If methane begins to burn in the screen, the lamp should be carried out to pure air and it should not be jerked or rapidly moved. If it is impossible to remove the lamp from the gas area, it should be carefully extinguished by turning the wick down as low as possible and covering the air inlet holes so as to

smother the flame.

In addition to the hazards due to the toxic effects of certain gases, the atmosphere of a mine may be dangerous because of depletion of the oxygen content and its replacement by gases such as nitrogen or carbon dioxide. This condition may be detected by the flame safety lamp, chemical analysis, or other instruments designed for this purpose.

Hydrogen Sulphide Detectors

Hydrogen sulphide has been found in some Ontario mines. The Drager Gas Detector *(Fig. 12)* using hydrogen sulphide tubes will test for the presence of the gas.

Other Mine Gases

Some mine gases can be detected by odour, taste, or by irritation of the eyes and respiratory passages. Sulphur dioxide is an outstanding example.

Questions on Chapter III

1 Describe the method or methods for detecting the following:
   (a) Carbon Monoxide
   (b) Methane
   (c) Deficiency of Oxygen

2 How do you prepare the flame lamp before making a test?

3 Describe "Fuel Cap" and "Gas Cap" as seen on the flame lamp under certain conditions.

4 (a) Describe the components of the Drager Gas Detector
   (b) What are the two test ranges of the most used detector tube. (10 b) (low range).

5 What precautions must be taken when testing diesel exhaust gases with either carbon monoxide detector?

Chapter IV

Methods of Protection Against Mine Gases

General Considerations

The general requirements and approvals of breathing devices as laid down by the *U.S. Bureau of Mines have been generally accepted by the Ontario Ministry of Labour Mining Health and Safety Branch, which authority also recognizes applicable recommendations of other like qualified bodies.

Respiratory Protection

Breathing apparatus will prevent poisons entering the body through the respiratory system, but will not protect against poisoning through the skin.

Protective breathing equipment may be identified by its method of operation and is classified as self-contained closed-circuit, self-contained open-circuit or gas mask.

Self-contained closed-circuit apparatus used in mine rescue operations differ in design and may use either compressed, liquid or chemically produced oxygen which when breathed is circulated through a carbon dioxide absorbing chemical compound and rebreathed. Drager BG 174 is in this classification.

Self-contained open-circuit apparatus uses purified compressed air which once breathed is passed to the ambient air and not re-used. The demand apparatus fits this classification.

Gas masks are air purifying devices designed solely to remove specific contaminants from the air, it is essential that their use be restricted to atmospheres which contain sufficient oxygen to support life. The Type N gas mask is in this category.

No practical method of breathing protection should be

considered perfect. The physiological structure of man is such that it precludes the manufacture of a portable apparatus that will suit all men on all occasions and for all purposes. It is a simple matter to use a breathing apparatus for a period of time in known safe and normal conditions, this is within the scope of most people, but to wear breathing apparatus in an emergency situation where high temperature, poor visibility and arduous work add to the emotional and physical stress, constant training in simulated emergency conditions is essential so that the wearing of the breathing device itself does not become part of the problem.

The Value of Slow, Deep Breathing When Wearing Apparatus

To use gas masks or other breathing devices properly, the art of deep breathing should be practised until it becomes habitual. The value of slow, deep breathing at all times can be demonstrated whether wearing breathing devices or not. This is best shown by doing some exercise that causes panting or quick breathing. Draw in several deep, controlled breaths, slowly and evenly, inhaling as much air as possible. It will be noticed that the normal rate of breathing can be resumed quickly and easily without panting.

Heat and resistance through the apparatus must be expected when breathing devices are worn. The resistance can vary from slight (negligible) to as much as 20 to 30 kPa, and must be overcome. The heat may vary from normal to an intolerable temperature depending upon the type of apparatus and local conditions. If the apparatus wearer is breathing fast he cannot overcome the resistance and obtain sufficient air before he starts to exhale. When this condition arises the wearer begins to suffer from ''air hunger''. This in turn induces a suffocating feeling and the tendency is to remove the breathing device at all costs. When wearing a breathing device of any make or type, deep,

slow breathing is essential and can only be attained by continual practice.

Gas Masks for Protection Against All Gases, Smokes and Vapours in Air Containing Sufficient Oxygen to Sustain Life

In its investigations of gas masks for use in mining and allied industries the *U.S. Bureau of Mines has studied and developed various types of masks for protection against noxious gases and fumes that may be present in atmospheres found in mines, metallurgical works, chemical and other industries. As a result of these investigations the Bureau issued a schedule of tests under which manufacturers may submit masks for approval. In this schedule canisters are classified by the type of gas removed, as follows: A, acid gases; B, organic vapours; C, ammonia; D, carbon monoxide; E, Smoke, dust and mist; F, special gases; (e.g. hydrocyanic acid used for fumigating) and N, all mine gases, vapours and smoke. Each type carries an approval number which identifies it and its limitations. Each type of canister is distinctively coloured.

**Now certified by NIOSH/MSHA*

The Type N Gas Mask

The Type N Gas Mask is an approved respiratory device used in the mines in Ontario. Due to its limitations the wearer should be well trained and physically capable.

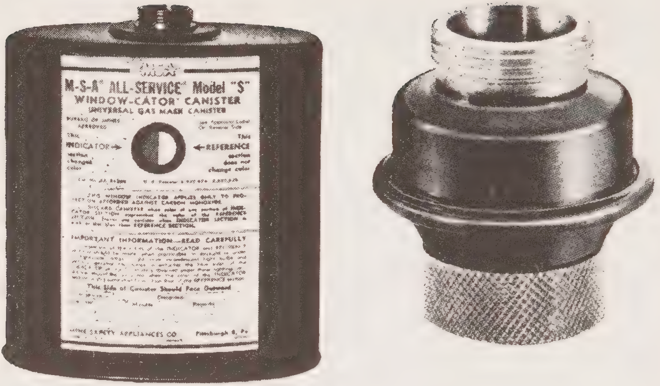
The essential parts of a Type N mask consist of a facemask attached by a flexible tube to a check valve connected to the top of a canister containing the chemicals for purifying the air. The canister is held in a harness supported by a strap around the body and suspended from the neck.

The weight of the complete equipment is 2.5 kg (5¾ lb.). The canister weighs 1.5 kg (3½ lb.).

Fig. 22 — Type N Mask Being Tested by Mine Rescue Team

Facemask

The facemask forms a pocket for the face and permits breathing through the nose or mouth. The wearer can carry on a conversation with a person nearby or over a telephone, although the voice is muffled. A corrugated, flexible rubber tube carries the inhaled air from the canister to the facemask. The inhaled air is drawn into the facemask through tubes which discharge against the lens. The air is dried in passing through the canister, and this prevents serious fogging of the lens. Exhaled air passes out through a check valve. Adjustable rubber headbands hold the facemask firmly against the face.



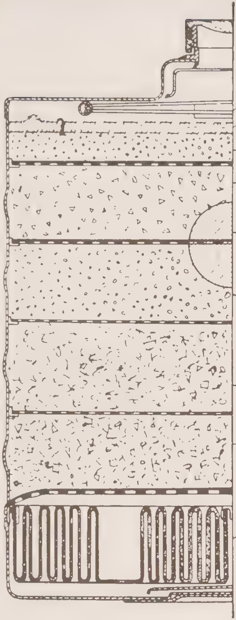
(a) (b)

Fig. 23 — (a) MSA Type N Canister, (b) External Check Valve

Canister

The Type N canister is used in Ontario. It has been found to give limited protection against all mine gases, vapours and smoke. It may not give protection against the toxic smokes of modern warfare nor of fires involving certain plastics or chemicals. It is not recommended to be used for firefighting or where the atmosphere contains less than 19.5 per cent of oxygen.

Fig. 24 shows the detail of the canister with the arrangement of the contents. Since the window indicating canister does not contain valves, an external check valve must be used between the facemask and the top of the canister to prevent exhaled breath from being returned to the canister. A dome-shaped screen above the bottom opening supports the materials and allows the ready distribution of incoming air over the entire cross section. The granulated absorbents are of 8 to 14 mesh



NOTE: Type "H" Canister same as above except that a higher efficiency filter is used to protect against radioactive particles, Beryllium dusts and fumes, living organisms and extremely finely divided and/or particulate matter.

Fig. 24 — (c) Section through MSA Type N Canister.

size, and are in horizontal layers in the canister so that the inspired air passes through each layer of the chemicals. The layers are separated by screens, and the whole is held in place by a screen at the top.

Noxious gases are removed from the air passing through the canister in the following manner:

1. Acid gases such as chlorine, hydrogen sulphide, and sulphur dioxide are removed by chemical reaction with the caustic agent (caustite, limite, etc.)

2. Organic vapours such as acetone, aniline, benzine, chloroform, formaldehyde, and gasoline are absorbed in the activated charcoal.

3. Ammonia gas is absorbed in the silica gel.

4. Carbon monoxide gas is oxidized by the oxygen in the air into carbon dioxide through the catalytic effect of the Hopcalite. The Hopcalite is placed above the other absorbents so that a minimum of moisture reaches it.

5. The purpose of the calcium chloride in the canister is to remove water vapour from the air, as moisture destroys the efficiency of the Hopcalite. The canister, (*Fig. 23)*, contains a small round window in the front of the canister, behind which are two coloured panels. The left panel is dark blue and the right is light blue. When sufficient moisture penetrates the Hopcalite to render it ineffective against carbon monoxide, the dark blue panel will have faded to and matched the light blue colour. Continued use will cause it to turn pink.

6. Smoke, dust and mists are removed by a filter. The specifications of the U.S. Bureau of Mines call for a 50 per cent filtering efficiency against smoke. In service the apparent filtering efficiency is considerably higher. The

fact that the smoke may be recognized by the wearer does not necessarily indicate a facemask leak.

It is important to note that the conversion of carbon monoxide to carbon dioxide generates heat; a wearer not aware of this chemical reaction may find it intolerable to breathe. Type N gas mask canisters are ***Red*** and are the only ones to be used with an approved facemask underground. However, the important precaution of never to enter an atmosphere which contains less than 19.5 per cent of oxygen or more than 2 per cent of harmful gases ***(3 per cent ammonia)*** must be observed when using the type N gas mask.

Procedure Testing, Adjusting, and Wearing Type N Mask

Carefully examine the various parts to ascertain that the mask is in wearable condition. The canister should be fresh and the bottom seal in place. The rubber parts should be elastic and the lenses clean and in good condition. Be sure the check valve is installed between the facemask and the canister. Examine the window indicator to be certain a noticeable difference in colour appears in the papers beneath it.

Field Tests

Only new canisters may be used at the time of an emergency. The following must be carried out in fresh air immediately before wearing the mask in a contaminated atmosphere.

1. Remove the three parts of the case; facemask, canister with harness, check valve.
2. Inspect the harness for damage, then canister, seals top and bottom, and window indicator.
3. Obtain new canister if required.
4. Hang straps around neck, adjust harness and remove top seal of canister.

5. Inspect external check valve, if separate, attempt to blow air into and draw air through it.

6. Check gasket on bottom of check valve and install on canister.

7. Inspect facemask and breathing tube for damage or deterioration.

8. Check gasket on breathing tube and connect to check valve.

9. Put on mask and adjust the straps.

10. Exhale to check the exhalation valve and attempt to inhale to verify the equipment to be airtight.

11. Remove the seal from the bottom of the canister and take a few breaths through the apparatus.

A lighted flame safety lamp or other oxygen indicator must be carried, whenever gas masks are worn, to indicate that enough oxygen is present to support life. Gas masks must never be used where a flame safety lamp will not burn with a normal flame, or where it would be dangerous to use the lamp, or the oxygen content of the atmosphere is below 19.5 per cent.

Life of Canisters for Different Gases

When noxious gases, with the exception of carbon monoxide, pass successively into the canister a portion of the absorbing capacity of the chemical is expended. As the end of the life of a canister approaches, a very small quantity of gases will pass, and may be detected by the sense of smell or irritation of the eyes, etc. This condition will gradually increase, and will serve as a warning to retreat.

The life of a canister for protection against carbon monoxide is shortened by the passage of air, regardless of

whether or not noxious gas is present because water vapour is always present in the air. The hopcalite fails to function when the moisture saturates it. Because of the presence of carbon monoxide, the length of time that a standard canister can be safely used has been set at 2 hours. The window indicating canister may be safely used for protection against carbon monoxide until the dark blue indicating colour fades and corresponds to the light blue colour beside it. As carbon monoxide cannot be detected by the senses a canister must be discarded when actual penetration of any gas is detected whether the 2-hour time limit has elapsed or not. Mixtures of noxious gases may be encountered, and in such a mixture one gas is usually predominant. During fires or after explosions the distillation products of wood containing ammonia and organic vapours may be found. Sulphur dioxide may be present, but carbon monoxide always constitutes the major hazard. The canister of the Type N mask will protect the wearer when the total of the poisonous gases does not exceed 2 per cent.

High Resistance or High Temperature in Canisters

The heat and resistance of a canister to breathing usually increases to an intolerable point before any carbon monoxide penetrates to the facemask. The reason is that carbon monoxide in excess of 2 per cent will cause so much heat to be generated by the chemical reaction that the inspired air will be intolerable to the wearer. More than 2 per cent of carbon monoxide is rarely encountered where a flame safety lamp will burn. A lighted flame safety lamp must be carried when gas masks are being worn.

Precautions When Using Type N Masks

1. Use gas masks only where a flame safety lamp will burn and where it is safe to use the lamp.

2. If the flame safety lamp indicates a lowering of the oxygen content, return to fresh air immediately.

3. Do not use any other than Type N canisters with the approved facemask. These canisters are all painted solid ***Red.***

4. The Type N canister may be used for up to two hours providing:
   (a) a new canister is used;
   (b) Excessively high moisture content is not in the atmosphere;
   (c) The concentration of gases does not reach 2 per cent. With 2 per cent carbon monoxide present the canister is rated for one hour only.

5. When the Type N Mask is worn, whether in training or actual use, the wearer will find that it is to his advantage to learn the art of slow, deep breathing even when doing strenuous manual labour.

6. When penetration of any gas is detected the wearer must go to fresh air immediately, and the canister must be exchanged for a new one.

Limitations of Use

The limitations of use of the Type N mask in air are exceedingly important. Gas masks do not supply the oxygen necessary to life; they can only remove relatively small percentages of noxious gases from air. Normal air contains nearly 21 per cent of oxygen. ***Wearers of masks should make sure that 19.5 per cent or more of oxygen is present in the air.*** This may be determined by means of a flame safety lamp. Where the flame burns there is enough oxygen for a man to breathe, but the flame will go out when only 16.25 per cent of oxygen is present. The gas mask does not provide protection in

covered tanks or other confined spaces, in vaults or cellars without ventilation, or in unventilated wells, shafts, pits, or parts of mines where fires, or explosions may have consumed the oxygen, or where large quantities of poisonous or asphyxiating gases or vapours may have been formed. Because of the dangers of oxygen deficiency in the atmosphere, the necessity of caution in the use of gas masks cannot be too strongly emphasized. In such deficient atmospheres, self-contained breathing apparatus, which provides complete protection, must be used.

Carbon Monoxide Self Rescuers

General

''Self Rescuers'' are one time use devices ***for escape purposes only.*** Types described here are the MSA W-65 and the Drager FSR 810. Their rugged construction allows them to be carried by personnel while at work or be mounted on mobile equipment ready for instant use. Used under these conditions they are approved for a five-year period.

Carbon monoxide self rescuers do not give protection against any other noxious gas nor from a deficiency of oxygen. The presence of carbon monoxide will be indicated by heat generated in the self rescuer. Both types will provide adequate protection for 60 minutes in one per cent concentration of carbon monoxide. At 2 per cent carbon monoxide concentrations, the heat generated by the chemical reaction of the Hopcalite will be almost unbearable. All units have a built-in heat exchanger to help reduce the temperature of the air reaching the wearer's mouth.

The self rescuer MUST be kept on and used, regardless of the heat generated until the wearer reaches safety.

Description MSA W-65

This unit comes enclosed in an easily opened, hermetically sealed stainless steel case. The entire unit weighs 1 kg. It consists of an outer coarse dust filter and an inner fine dust filter for the removal of solid particles suspended in the atmosphere, a charge of hopcalite and a drying agent to protect the hopcalite from moisture which would destroy its ability to oxidize carbon monoxide. The rubber mouthpiece contains a saliva drainer to prevent moisture from reaching the filtering chemicals. The nose clip prevents breathing through the nose and is attached to the device by a cord. The self rescuer is held in the wearing position by an adjustable head harness.

Fig. 25 — Man Wearing MSA W-65 Self Rescuer

To Use:

1. Pull the red lever up hard to break the seal. Remove the top cover and discard.

2. Pull mask from case.

3. Insert mouthpiece between lips and teeth, bite on the lugs. Adjust head harness to support respirator. Adjust nose clip on nose.

4. ***Breathe only through the self rescuer.***

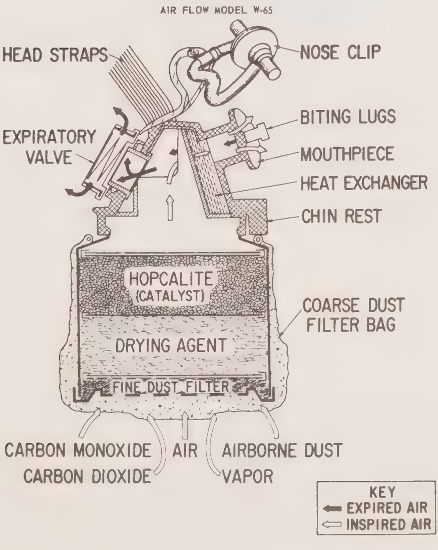


Fig. 26 — Diagrammatic Sketch of MSA W-65

Drager Model FSR 810

The Drager self rescuer is enclosed in a hermetically sealed plastic case carried in a soft vinyl carrying pouch. The filter consists of a coarse dust filter bag with a fine dust filter in the bottom. A layer of drying agent below the hopcalite absorbs moisture from the inhaled breath.

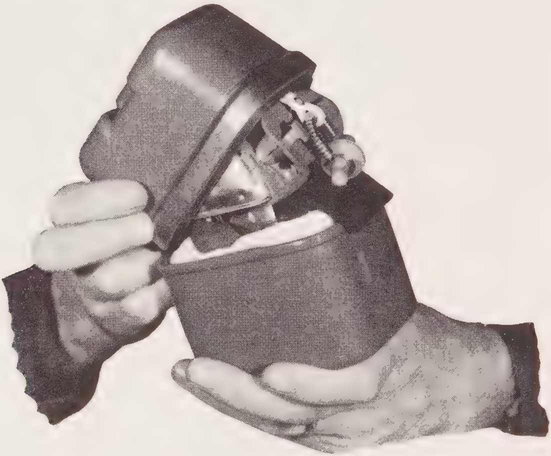


Fig. 27 — Drager FSR 810 Being Opened.

The dried air then passes through the hopcalite which converts any carbon monoxide to harmless carbon dioxide. A mesh of fine wire dissipates the heat generated by the reaction of carbon monoxide and the hopcalite. Exhaled breath passes out through a spring-backed mica exhalation valve. A rubber nose clip prevents breathing through the nose when the rubber mouthpiece is in place. A headstrap supports the mask while in use.

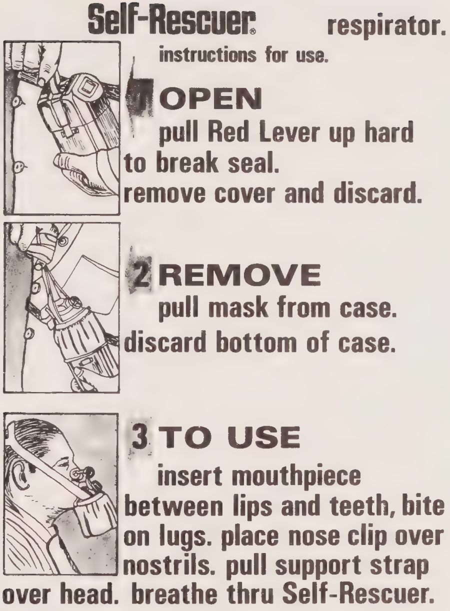


Fig. 28 — Self Rescuers — Instructions for Use

To Use

1. Remove from the carrying pouch and break the seal by raising the lever on the top of the case.
2. Discard the top half of the case and pull the mask out of the bottom half.
3. Insert the mouthpiece between the lips and teeth and hold in place by biting on the rubber lugs.
4. Adjust the nose clip and head harness. ***Breathe only through the self rescuer.***

Self-Contained Oxygen Breathing Apparatus

Physiological Effects of Breathing Pure Oxygen

The quantity of oxygen consumed by the body varies with the amount of energy expended. A man at rest consumes approximately 700 cubic centimetres per minute (16 cubic inches). During violent exercise the consumption may increase to more than 8 times that amount, but the body consumes no more oxygen than it requires.

Fig. 29 — Man Wearing Drager BG 174 Apparatus

The pure oxygen breathed by the wearer of a self-contained oxygen breathing apparatus causes no noticeable ill effect, even after several successive periods of use, unless the wearer is subjected to air pressures in excess of the normal atmospheric pressure of 1.0133 bar., (14.7 psi) such as might be encountered in caisson work.

The Elimination of Dangerous Amounts of Carbon Dioxide in the Circulatory System of the Apparatus

One of the most important functions of any closed-circuit self-contained oxygen breathing apparatus is the elimination of dangerous amounts of carbon dioxide from the circulatory system of the apparatus.

In an open-circuit demand type apparatus using compressed pure air, the exhaled air passes through a valve to the outside atmosphere.

The Drager BG 174 apparatus uses two methods of carbon dioxide removal.

1. A disposable alkaline cartridge.
2. A refillable canister which utilizes a soda lime compound known by such trade names as Dragersorb, Safe-T-Sorb and Cardoxide.

The alkaline cartridge has advantages over the soda lime method.

1. It will provide protection for four hours.
2. Moisture absorption is more efficient.
3. Inspired air feels cooler.
4. Resistance to breathing is lower.

The Drager Self-Contained, Oxygen Breathing Apparatus Type BG 174

General Description

1. The Drager self-contained closed-circuit, oxygen breathing apparatus carried on the back enables the mine rescue worker to enter irrespirable and toxic atmospheres. The

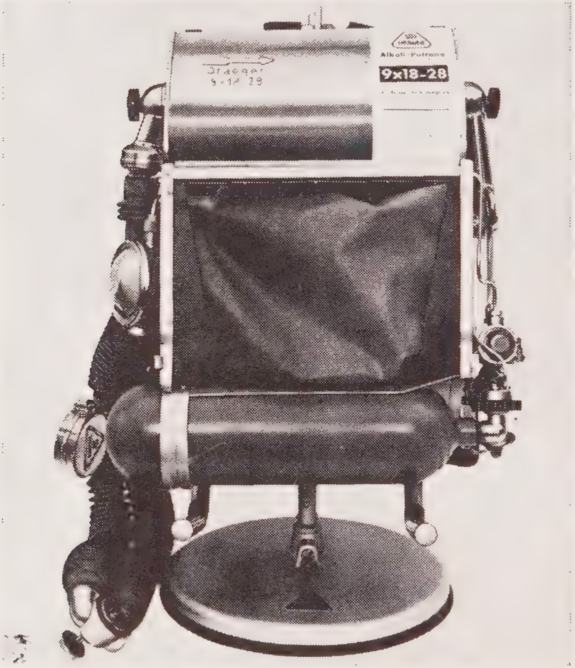


Fig. 30 — BG 174 Opened on Stand

apparatus permits the wearer to breathe independent of the atmosphere and enables him to effect rescue and recovery under extremely arduous conditions.

2. The apparatus is light in weight: 12.3 kg (28 lb.), but its construction is rugged and highly resistant to mechanical shock. The exhaled air is freed of its carbon dioxide content in a regenerative canister and passed into a breathing bag. The air purified in this way is then withdrawn from the breathing bag during inhalation.

3. The oxygen consumed during respiration is replaced from a cylinder of compressed oxygen through a constant flow metering orifice at the rate of 1.5 litres per minute; if this is not sufficient additional oxygen is provided by a lung governed demand valve.

4. When the apparatus is initially turned on, the circuit is automatically flushed with approximately 6 litres of oxygen. Apart from the occasional checking of the oxygen supply by observing the pressure gauge, the apparatus requires no further attention during its use.

Description of Parts

The apparatus consists of six main parts:

1. Oxygen bottle
2. Oxygen control assembly
3. Valve assembly
4. Breathing tubes and facemask
5. Regenerative canister
6. Breathing bag

1 **The Oxygen Bottle** is a high grade alloy steel cylinder with a volume of 2 litres. When charged to a pressure of 135 bar (2,000 psi or 13,800 kPa) it contains approximately 270 litres of oxygen, and at its maximum pressure of 200 bar (3,000 psi or 21,000 kPa) it will contain approximately 400 litres. The bottle must be hydrostatically tested every five years to comply with the regulations of the Canadian Transport Commission. The testing pressure is 300 bar (4,400 psi or 30,000 kPa).

The bottle valve is equipped with a safety cap which will permit the oxygen to escape when the internal pressure of the cylinder reaches 276 bar (4,000 psi) and so prevent rupturing of the bottle under excessive pressure. This may occur during recharging or when the bottle is exposed to high temperatures during storage.

2 **The Oxygen Control Assembly** is made of brass and is attached to the right hand wall of the carrying frame. It contains;
(a) reducing valve,
(b) preflushing unit,
(c) a manually operated bypass valve, and
(d) a valve for the pressure gauge line. This assembly is coupled to the oxygen bottle by a hand tightened connector.

3 **The Valve Assembly** attached to the left hand sidewall of the frame controls the delivery of oxygen to the wearer, and consists of:
(a) metering orifice designed to allow a constant flow of 1.5 litres per minute,
(b) a demand valve to provide additional oxygen if required,
(c) inhalation and exhalation valves,
(d) warning device,

(e) pressure relief valve,
(f) check valve, and
(g) connections for the breathing tubes.

4 **Breathing Tubes and Facemask** — the corrugated inhalation and exhalation rubber tubes are attached to a manifold to which the facemask is connected. The manifold is designed to direct moisture into the inhalation hose to which is attached a moisture trap. The individual couplings on the free ends connect to the valve assembly. The facemask has a curved full view lens with a manually operated wiper to keep the inside surface clear. The neoprene mask body with an inner mask face seal is held in place by a five-strap quick adjusting head harness.

5 **The Regenerative Canister** in which carbon dioxide is removed from the exhaled breath may be one of two types.
(a) A disposable alkaline cartridge which may be used for a continuous period of up to four hours. This cartridge provides drier air, therefore, the wearer is under less physical stress than when using the refillable type.
(b) Refillable canisters are of two designs, both of which may be used for up to three hours and contain 3 kg ($6^3/_4$ lb.) of carbon dioxide absorbent.

6 **The Breathing Bag** is made of a three-ply rubberized fabric. It is arranged within the apparatus frame so that it is protected on all sides and is able to function freely. It is connected to the valve assembly by a threaded coupling and to the regenerator by an elbow connection. The minimum capacity of the breathing bag is 6 litres.

Auxiliary Parts

1 **The Frame and Harness:** — The frame is made of corrosion-resistant light alloy. The flat side walls, together

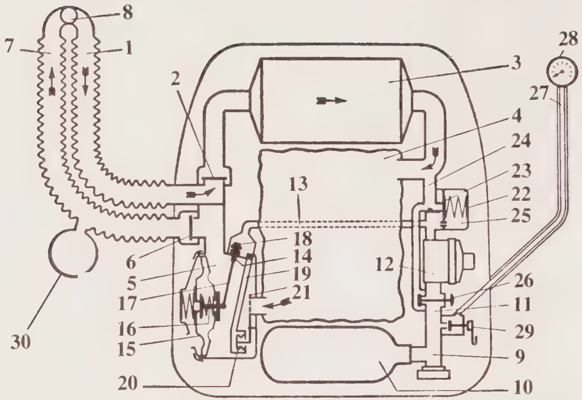


Fig. 31 — Circuit of the BG 174

Function of the Apparatus

1	exhalation tube	**17**	demand valve lever
2	exhalation valve	**18**	demand valve seat
3	regenerative canister	**19**	bellows line
4	breathing bag	**20**	warning signal bellows
5	valve assembly	**21**	warning signal flap
6	inhalation valve	**22**	preflush unit
7	inhalation tube	**23**	preflushing control valve
8	breathing tube/ facemask manifold	**24**	preflush and bypass valve
9	bottle valve	**25**	diaphragm chamber
10	oxygen bottle	**26**	manual bypass valve
11	oxygen control assembly	**27**	pressure gauge tube
12	reducing valve	**28**	pressure gauge
13	oxygen line	**29**	gauge valve
14	metering orifice	**30**	moisture trap
15	control diaphragm		
16	relief check valve		

with the curved plates of the regenerative canister support at the top, and the cylinder support at the bottom constitute a compact frame. The back plate acts as a protective wall for the breathing bag. All fittings of the apparatus are attached to the strong sidewalls. The regenerative canister support is so arranged that the canister itself is properly cooled, and the transfer of heat to the back of the wearer by conduction and radiation is minimized.

The rear of the frame is provided with a resilient pad of rubberized fabric with a steel insert, ensuring a comfortable fit, and proper spacing of the apparatus from the body of the wearer.

The harness is made of nylon cotton fabric which is comfortable to wear and easily adjusted.

2 **The Cover** protects the complete apparatus and is easily removable.

3 **The Gauge Tube and Gauge:** — The tube is a rubber covered, high pressure, flexible, close wound spiral metal tube. The clear easy-to-read pressure gauge is fitted with a swivel connection to facilitate correct positioning.

Closed Circuit Operation

The exhaled air containing carbon dioxide flows from the mouth through the exhalation tube (1), to the exhalation valve (2), and then to the regenerative canister (3), where the carbon dioxide is absorbed. The absorption process is accompanied by the production of heat, increasing the temperature of the canister and the air flowing through it. The air, now purified, flows into the breathing bag (4).

During inhalation, the air is drawn from the breathing bag and flows through the valve assembly (5), to the inhalation valve (6), the inhalation tube (7), to the facemask manifold (8). The air within the apparatus is inhaled and exhaled in a closed

circuit. Its direction of flow is controlled by valves (2) and (6) in the valve assembly.

Constant Flow Metering

In normal operation, the oxygen consumed during breathing is replaced by a constant flow metering action at the rate of 1.5 litres per minute. With the bottle valve (9) open, high pressure oxygen flows from the bottle (10), to the reducing valve (12), located in the oxygen control assembly (11). The oxygen pressure is there reduced to 400 kPa (57 psi) at which it flows through the oxygen line (13), the metering orifice (14), and into the valve assembly (5) where it replenishes the closed-circuit air.

Relief Check Valve

If the oxygen consumption is less than the supply through the constant flow metering system, the breathing bag becomes over inflated during exhalation. The excess pressure thus produced in the breathing bag causes the control diaphragm (15) in the valve assembly (5) to move to the left against a spring. An orifice in the centre of the diaphragm is equipped with a sealing lip which is lifted off a sealing plate, enabling the excess air to flow through the diaphragm and escape through a check valve to the outside air.

Automatic Demand Valve

Under conditions of extreme physical effort, the oxygen requirement may exceed that supplied by constant flow metering. In such circumstances the breathing bag fills insufficiently with each breathing cycle until finally its contents no longer supply the wearer with oxygen. A negative pressure is then created which immediately activates the diaphragm (15) of the valve assembly (5). The sealing plate of the relief valve (16) is then activated so that a plunger pushes the lever (17) to open the demand valve (18). Oxygen then flows through the oxygen

line (13) into the valve assembly (5) and into the inhalation chamber until the requirements are satisfied.

Warning Signal

The oxygen line (13) is in series with the bellows line (19) inside the valve assembly (5). When the bottle valve is opened the oxygen line is pressurized, the bellows line is pressurized and the bellows (20) is compressed. In the compressed position the bellows keeps an acoustic reed (21) in the open mode.

The bellows controls the double-arm lever for the warning signal flap. When the apparatus is not pressurized the bellows control closes the flap. An attempt to breathe will draw the air from the breathing bag and will activate the acoustic reeds. A clear musical note alerts the wearer that the bottle valve is not open.

Preflushing Unit

When the oxygen bottle valve is opened, oxygen flows through the reducing valve (12) to the preflushing unit (22). The pressure opens the control valve (23) so that oxygen flows through the preflushing line (24) into the circuit and fills the breathing bag. Simultaneously, oxygen flows through an orifice into the diaphragm chamber (25) of the preflushing unit. As soon as pressures are balanced on each side of the diaphragm, the valve (23) is closed by spring pressure, thus completing the preflushing process. The preflushing unit functions so that a minimum of 6 litres of oxygen flows into the apparatus during this action.

Manual Bypass Valve

Depressing the button of the manual bypass valve (26) causes oxygen to flow from the high pressure side of the oxygen control assembly directly to the preflushing line (24) and from there into the circuit. This emergency oxygen supply is thus independent

of the reducing valve, the demand valve and the constant flow metering orifice.

Pressure Gauge and Gauge Tube

The gauge tube (27) branches from the high pressure side of the oxygen control assembly. The pressure gauge (28) is provided with luminous markings on the dial and pointer so the bottle pressure can be checked in darkness.

The gauge tube may be closed by a valve (29) in the event of a leak in the tube or gauge.

Field Tests

These tests should always be made immediately before the apparatus is used. This assures the wearer that the apparatus is satisfactory for use without taking the word of any other person. Should the wearer not be satisfied that such is the case, he should report to the person in charge and not "get under oxygen".

Fig. 32 — Testing BG 174 With Universal Tester

Fig. 33 — Testing BG 174 With Negative Leak Tester

These field tests have been devised to give him that assurance.

With the aid of the apparatus testers *(Figs. 32 and 33)* and without spending much time, the operator can ascertain the apparatus meets his approval by means of four simple tests.

These tests, for the greatest efficiency, should be carried out in the same order as they appear below.

See that all the necessary items of equipment are present and complete and await team captain's orders.

1. Set up: antifog, tissue, testers, soda lime, funnels.
2. Lay apparatus case on floor, ready to open.
3. Await order from captain to begin testing.

Preflush and Bottle Pressure Test

1. Remove everything from case, place on bench, and close cover of the apparatus case.

2. Have apparatus resting on cover with bottle toward team member.
3. Examine lamp belt and link line and put on D ring to right.
4. Examine complete harness and remove all dust caps.
5. Remove gauge from its cover and open cylinder valve about $^{1}/_{2}$ turn.
6. Note preflush (audible sound) and bottle pressure on gauge.
7. Close cylinder valve and observe pressure on gauge dropping slowly to indicate oxygen flow and open bypass valve to finally reduce gauge to zero.
8. Replace gauge in cover and stand the apparatus up with the back spanning toward the team member.

Regenerator Test

1. Remove apparatus cover and place it on top of the case.
2. Remove and completely fill the regenerative canister or obtain new alkaline canister.
3. Inspect filler plug and gasket and replace on canister.
4. Install canister in apparatus, align arrows.
5. Inspect coupling gaskets and make corrections on both sides of canister.

Negative Pressure Leak Test

1. Inspect breathing tubes, moisture trap plug and gaskets.
2. Connect tubes to apparatus with moisture trap down.
3. Check for gasket and connect tubes to leak tester.
4. Inspect breathing bag then collapse it using hands.

5. Depress release button on leak tester and aspirate bulb until needle of tester reaches the upper end of the scale.
6. Remove aspirator bulb and reduce pressure using release button until needle is in the green area on the dial (approx. 70 mm water gauge pressure).
7. Observe the needle for a minimum of 10 seconds.
8. Disconnect tubes from tester and replace cover on apparatus.
9. Put on the apparatus and adjust harness *(Fig. 35)*.

Facemask Test

1. Inspect facemask and saturate wiper with antifog solution.
2. Lay facemask on table, check gasket on the breathing tube manifold and attach facemask.
3. Put on facemask and adjust straps.
4. Inhale and exhale to test warning signal.
5. Squeeze off both tubes and inhale to test facemask seal.
6. Squeeze off tubes individually, inhale and exhale to test valves.
7. Remove facemask and hang it with harness.
8. Put unnecessary items back in apparatus case.
9. Await request and report results to the team captain.

Fig. 34 — Removing Cover of the Apparatus

Getting Under Oxygen

1. Await order from Team Captain.
2. Open bottle valve fully, close 1/2 turn and observe pressure on gauge.
3. Put on and adjust facemask.
4. Squeeze both tubes and inhale to test facemask seal.

Fig. 35 — Opening the Oxygen Bottle Valve

Getting Out of Oxygen

1. Await order from Team Captain.
2. Remove facemask.
3. Close bottle valve.
4. Return gauge to zero.
5. Report to Team Captain.

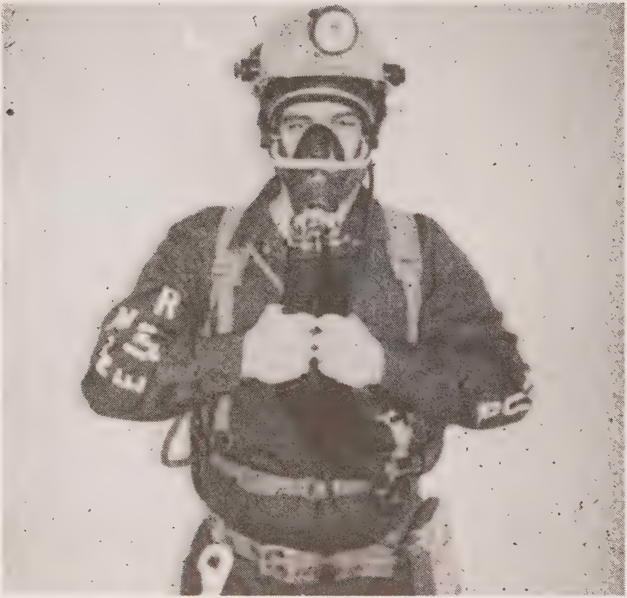


Fig. 36 — Checking for Tightness of the Facemask

Cleaning and Sterilization of Breathing Apparatus

Breathing apparatus should not be used while wearing soiled clothing. Clean coveralls should be provided for both training and emergency operations.

Cleaning of the apparatus after each period of use is the responsibility of the person using it. All dirt must be washed or sponged off the cover and harness etc. For hygienic reasons the facemask, breathing tubes and breathing bag should be washed, placed in a sterilizing solution, rinsed thoroughly, and dried. After cleaning, the apparatus must be assembled, tested and

Fig. 37 — Team Members Wearing Drager BG 174 Apparatus

replaced in the carrying case.

The sterilizing solution may consist of any commercial germicide proven to be harmless to the rubber parts and used as recommended by the manufacturer.

The valve assembly should be sterilized periodically when in regular use.

Alkaline cartridges should be resealed after use and properly disposed of. Refillable canisters must be emptied after each use and replaced in the apparatus. Refilling of the canister must be done by the person who will wear it.

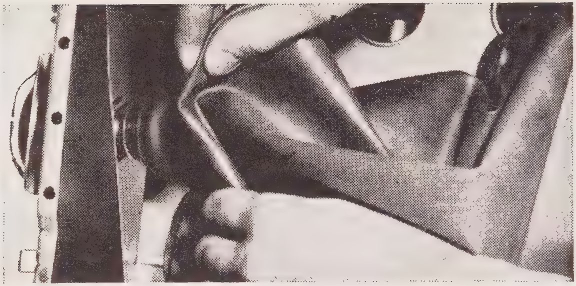


Fig. 38 — Removing the Breathing Bag

Station Tests (Using Universal Tester)

Exhalation and Inhalation Valves

Squeeze the breathing tubes one at a time by hand, and attempt to blow into, and subsequently to draw air from, the apparatus. If the inhalation tube is tightly squeezed it should not be possible to draw air through the apparatus. If the exhalation tube is tightly squeezed, it should be impossible to blow air into the apparatus.

Warning Signal

Adjust pointer of the Universal testing instrument to zero. Connect the breathing tubes to the tester. Set tester to "Negative Pressure Pumping" and empty the breathing bag with the pump. The warning signal should sound clearly at each stroke of the pump.

Negative Leak Test

Continue to empty the breathing bag until the pointer of the testing instrument is located between -80 and -100 mm. Set to "Leak Test" and adjust the pointer to -70 mm. No more than 10 mm of leakage is permissible over a period of one minute.

Preflush and Bottle Pressure

Close pressure gauge valve.

Open bottle valve and observe breathing bag which should fill. Observe gauge and open gauge valve. Check pressure on gauge.

Constant Flow Meter Test

Seal off the relief valve discharge port with the rubber plug provided. Set testing unit to "Dosage" 0.5 to 2.0 litres per minute. When the pointer comes to rest at the figure indicated on the red scale it will register the flow of oxygen through the apparatus. Permissible readings are between 1.4 and 1.7 litres per minute.

Relief Valve Test

Remove rubber plug, turn lever to "Leak Test". Where the pointer comes to rest indicates the opening pressure of the relief valve. Between +15 and +40 mm is permissible.

Demand Valve Test

Set lever at "Negative Pressure Pumping" and empty breathing bag by pumping. When the breathing bag is empty the demand valve will operate and a flow of oxygen will be heard. Observe the pointer reading on the negative scale. A reading of between -15 and -40 mm is permissible.

Manual Bypass Valve and Pressure Gauge Line

With bottle valve open, close the pressure gauge valve. Operate the manual bypass valve. There should be an audible flow of oxygen into the circuit, also a visible filling of the breathing bag. The pressure gauge reading should remain constant. Open pressure gauge valve and close the bottle valve to return needle to zero.

Positive Pressure Leak Test

Replace rubber plug in relief valve port and pump at "Positive Pressure Pumping" until the breathing bag is completely full. (+80 to +100 mm) switch to "Leak Test" and adjust pointer to +70 mm. No more than 10 mm of leakage is permissible over a period of one minute. Remove plug.

Remove the breathing tubes from the tester and seal the connections with the caps. Replace the cover on the apparatus and place back in storage.

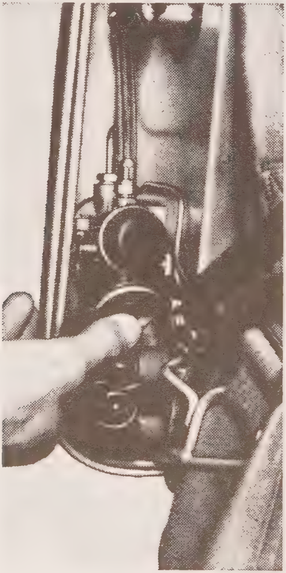


Fig. 39 — Using the Bypass

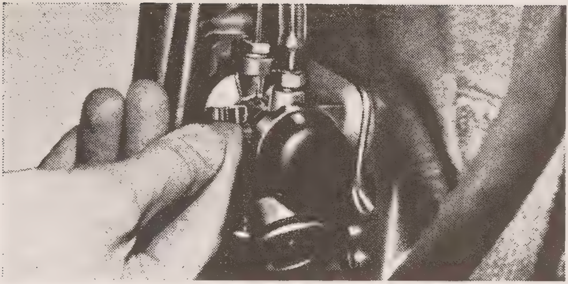


Fig. 40 — Operating the Gauge Valve

Maintenance of the Apparatus

Self-contained oxygen-breathing apparatus should be tested thoroughly every month. The following program should be carried out:

Thoroughly rinse the breathing bag and breathing tubes with clear, lukewarm water. The rubber components should be kneaded. If there is any alkaline fluid in any part of the apparatus, vinegar should be added to the rinsing water, after which all parts should be rinsed again with clean water. The components should be dried, away from direct sunlight. Compressed air should not be used in drying.

The condition of the valve assembly diaphragm should be checked at least once every year, and changed if any signs of wear or aging occur. The rubber inhalation valve and the rubber relief check valve should receive the same attention.

Care must be taken that the apparatus does not become damp or dirty in storage. Economies made on inadequate maintenance are lost in the costs of replacements.

Oil or other lubricants must not be used on any oxygen apparatus, particularly involving the high pressure connection or the bottle valve. Failure to observe this precaution may lead to

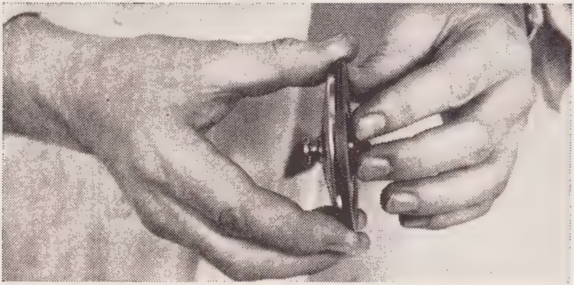


Fig. 41 — Checking the Movement of the Diaphragm

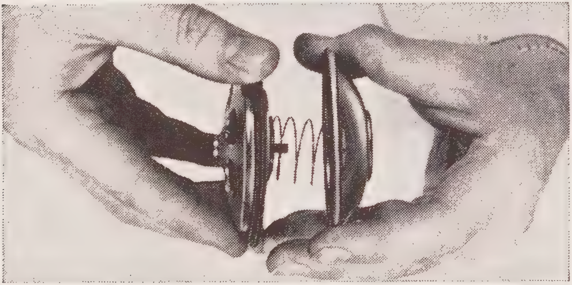


Fig. 42 — Inserting the Relief Valve Spring

an explosion.

The apparatus must not be stored in direct sunlight nor in hot areas.

Properly sealed alkali cartridges have a shelf life of at least six years.

Before installing a new alkali cartridge it should be checked for efficiency by shaking to determine that the chemical is not solidified.

All gaskets should be inspected and changed as required.

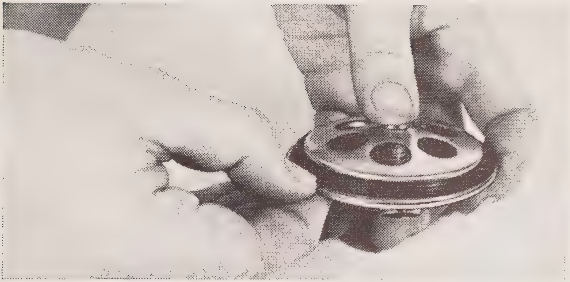


Fig. 43 — Fitting the Diaphragm Ring

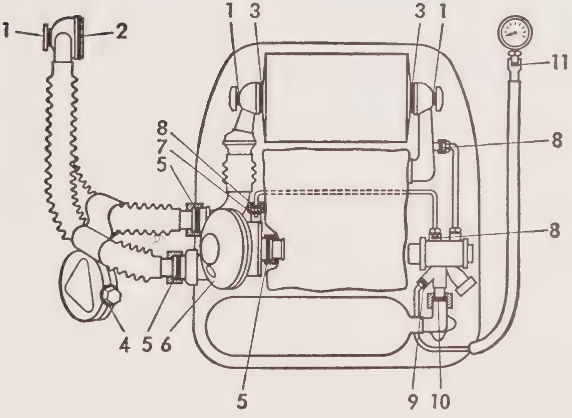


Fig. 44 — Location of Gaskets on the BG 174

A record should be kept for each apparatus showing the tests carried out and the test dates indicating the apparatus is stored ready for use.

Questions and Answers on Drager BG 174 Oxygen Breathing Apparatus

1 **What is the pressure in a fully charged oxygen bottle?**
Oxygen bottles in storage are charged to 200 bar (3,000 psi, 21,000 kPa).

2 **Why is it necessary to have a pressure gauge?**
The pressure gauge indicates the pressure in the oxygen bottle.

3 **How would you test for moisture in an oxygen bottle?**
Hold the bottle with the valve end down and open the main bottle valve. If moisture is present, it will show in the form of vapour.

4 **How would you test the oxygen bottle and the main bottle valve for air tightness?**
To test the oxygen bottle and the main bottle valve for air tightness, immerse the bottle and valve in water; bubbles indicate leaks. Place a metal cap on the outlet end of the main bottle valve, open the main bottle valve, and immerse the valve in water; escaping bubbles will show any leaks around the packing gland or stem.

5 **Why is a safety cap attached to the main bottle valve?**
A safety cap is attached to the main bottle valve to provide for the escape of oxygen without rupture of the cylinder during exposure to heat. The cap contains a disc that will rupture if the pressure is increased beyond the safety factor of the material.

6 **Why does a metal tube project from the end of the main bottle valve into the oxygen bottle?**
A metal tube projects from the end of the main bottle valve into the oxygen bottle in order to draw out oxygen free from sediment, moisture or rust.

7 Why is the apparatus equipped with a bypass valve?
The bypass valve is provided so that the wearer can be supplied with oxygen if some working part of the high pressure side fails.

8 When the bypass valve is opened, does the oxygen have a free, open course to the wearer's lungs?
Yes. The oxygen flows from the bottle directly into the pre flushing line and into the breathing circuit.

9 Is it a good policy to use the bypass valve when the automatic valves are supplying the wearer with sufficient oxygen?
The bypass valve should not be used when the automatic valves are supplying sufficient oxygen. Excessive pressure in the breathing circuit will cause loss and wastage of oxygen to the outside atmosphere through the relief valve.

10 How many turns should the main bottle valve be opened?
The main bottle valve should be opened to its fullest extent, and then closed one half-turn.

11 What is the function of the Demand Valve?
To provide additional oxygen to the wearer as required, during periods of increased or excessive work when the constant flow of 1.5 litres/min might not be sufficient.

12 What is contained in the Oxygen Control Assembly?
This unit contains the reducing valve, the preflushing unit, the bypass valve and the gauge valve.

13 What would you do if the gauge tube developed a leak?
If the gauge tube develops a leak, close the pressure gauge valve and return to the fresh air base. It is not necessary to use the bypass in this case.

14 What is the purpose of the breathing bag?
The breathing bag acts as a reservoir for the exhaled air.

15 What is the air capacity of the breathing bag?

The air capacity of the breathing bag is approximately 6 litres.

16 Why are flexible corrugated rubber tubes attached to the facemask?

The tubes allow free movement of the wearer's head and do not interfere with the circulation of air in the apparatus.

17 Why are there inhalation and exhalation valves on a breathing apparatus?

The inhalation and exhalation valves circulate the air in one direction, so that it can be purified and cooled.

18 How would you make the facemask test?

(a) Examine the rubber parts of the facemask and corrugated breathing tubes, paying particular attention to any scuffed or worn spots.
(b) Attach the facemask to the breathing tube connection. Put on and adjust the facemask. Inhale and exhale to test warning signal.
(c) Squeeze both tubes and inhale to test the facemask seal.
(d) Squeeze the tubes individually, inhale and exhale to test the valves. If the inhalation valve is operating, it should not be possible to exhale while squeezing the exhalation tube. If the exhalation valve is operating, it should be impossible to inhale while squeezing the inhalation tube. Any leaks in the facemask or breathing tubes should be reported and another unit obtained.

19 What percentage of carbon dioxide is given off in exhalation?

Approximately 4 to 6 per cent of carbon dioxide is given off in exhalation.

20 How many kilograms of carbon dioxide absorbent does a fully charged apparatus contain?

A fully charged apparatus contains approximately 3 kg. of absorbent. ($6^3/_4$ lb.).

21 How would you empty the apparatus and charge it with absorbent?

To empty the apparatus and charge it with absorbent, remove the screw cap of the regenerator, pour out the used material, and refill with fresh absorbent.

22 Why can prolonged work be done without building up resistance to breathing in the absorbent?

The chemical used for absorbing carbon dioxide does not change form and so does not block the air course.

23 How would you sterilize the apparatus?

By placing the facemask, breathing tubes and breathing bag in a sterilizing solution, then rinse well with clean water.

24 Describe the method of counteracting fogging of the lenses.

The wiper blade must be saturated with anti-fog solution during field tests and checked again before leaving the fresh air base. The saturated wiper is operated whenever necessary while the facemask is being worn.

25 Describe the circulation of oxygen through the Drager apparatus.

Please refer to sections on "Closed-Circuit Operation" and "Constant Flow Metering".

26 What are the main purposes of the tests of the breathing apparatus?

The main purposes of the tests of the breathing apparatus are to determine air tightness and proper functioning of the working parts.

27 Why is it necessary to examine apparatus connections?
It is necessary to examine apparatus connections to see that all gaskets are in place and the connections are airtight.

28 Why should a rescue team, after entering a poisonous atmosphere, stop soon after leaving fresh air for a short time?
A rescue team entering a contaminated atmosphere should stop near fresh air for a short time so that if a team member is not capable of proceeding on the trip the team can return to fresh air quickly without undue hazard. It also gives the team members an opportunity to adjust themselves to existing conditions and gives the captain time to recheck the team and the apparatus.

Other Types of Self-Contained Breathing Apparatus

Other types of self-contained breathing apparatus have been found useful under certain conditions. The Chemox Oxygen Breathing Apparatus, Demand types of breathing apparatus using compressed air and the Oxy-SR 45 M are described below. Owing to their limited time these apparatus are recommended to be used only as auxiliary equipment for mine rescue purposes.

Compressed air, if used in breathing apparatus, should be of high quality and purity, and contain at least 20.5 per cent of oxygen and not more than 5 ppm of carbon monoxide. Approved portable compressed air apparatus using an open circuit and demand type regulator are available. These include the Scott Air Pak, and the MSA Air Mask.

Chemox Oxygen Breathing Apparatus

The Chemox Oxygen Breathing apparatus is a self-contained, closed-circuit type employing a replaceable canister containing a chemical which reacts with the moisture in the exhaled breath, evolves a supply of oxygen for breathing requirements and absorbs the exhaled carbon dioxide. This apparatus has been approved for one hour by the U.S. Bureau of Mines. It affords the wearer complete respiratory protection in atmospheres which are gaseous or deficient in oxygen.

Parts of the Apparatus

The apparatus has six main parts: the facemask and breathing tubes, the frame and harness, the manifold, the breathing bag, the canister, and the time limit warning bell.

The facemask is full vision with a speaking diaphragm. It has corrugated rubber inhalation and exhalation tubes, fastened

respectively to the left and right hand series of a metal housing which holds the inhalation, exhalation and pressure relief valves and is connected to the lower part of the facemask. The breathing tubes are connected to the manifold by their respective couplings.

Frame and Harness

The frame consists of an aluminum breast plate and canister holder. These are covered on the outside with a padded, rubberized fabric to protect the wearer from the heat of the canister when in use. The frame is carried by webbing shoulder and waist straps. The canister is supported by a swinging bail, or stirrup, attached to the metal holder and is tightened into place against the manifold by means of a jack screw and hand wheel on the bail. A rubber gasket forms the seal between the canister and the manifold.

Manifold

The manifold is a metal distribution chamber or box attached to the top of the framework over the canister holder. A metal tube passes down through the centre of the manifold chamber and a cone-shaped socket casting at the bottom of the manifold fits into the neck of the cone for breaking the copper foil seal of the canister. The end of the tube has a coupling for attaching it to the exhalation tube. In the base of the manifold there is an opening leading to the chamber in the manifold. This opening connects to the right hand section of the breathing bag. A bracket on the side of the manifold carries an elbow which connects the left hand section of the breathing bag and the inhalation tube.

Breathing Bag

The breathing bag is made of rubberized fabric. It is divided into two sections, one on each side of the canister holder, connected

together at the top. The bag is held in position to the frame by the connections with the manifold at the top and by a bolt to the frame at the lower end of each section.

Quick Start Canister

The quick start canister is a metal container filled with an oxygen producing chemical (potassium superoxide). It is held in the holder between two sections of the breathing bag, and weighs four pounds before use.

An oxygen candle, fired by pulling on a cord lanyard, is attached to the bottom of the canister.

Warning Bell

The apparatus is fitted with a warning bell which is preset and warns the wearer when it is time to leave the working place. It is attached to the upper part of the manifold.

Oxygen Flow Through Apparatus

The flow of oxygen in the apparatus is shown in *Fig. 46*. During exhalation the flow is from the facemask through the right hand breathing tube, through the manifold chamber and the seal puncturing cone, and down the centre tube of the canister to the bottom. The air then flows up through the chemical, which absorbs the carbon dioxide and the moisture and liberates oxygen, to the top of the canister. From here the flow continues to the bottom of the right hand side of the breathing bag, from which it flows into the facemask through the left hand breathing tube.

Installing Quick Starting Type Canister

1. Lift up lip of plastic cap until seal is broken. Completely remove the remainder of the cap, exposing the airtight copper foil canister seal. ***This copper foil seal must be fully exposed before inserting canister.***

Fig. 45 — Man Wearing Chemox Oxygen Breathing Apparatus

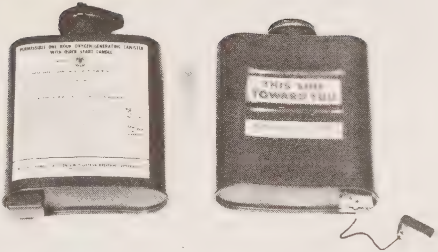


Fig. 46 — Quick Start Canister

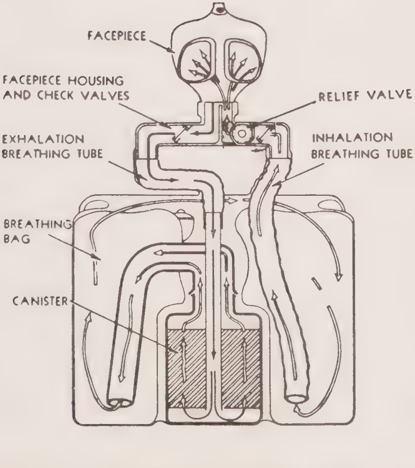


Fig. 47 — Oxygen Flow Through Apparatus

2. With the handwheel screwed down far enough for the bail to be swung outward, swing the bail outward and insert canister fully into canister holder with the smooth side to the front. The canister should be inserted sufficiently so that the copper foil seal is punctured and the rubber gasket fits snugly against recess in the plunger casting. Screw the handwheel clockwise until it is tight against the canister.

3. Remove candle cover by rotating swivel plate 180°. Pull swivel plate down, push cover toward centre of canister and let cover dangle. ***WARNING: Do not pull lanyard until ready for use:***

Note: The canister must be inserted with the smooth side to the front.

Wearing of Apparatus

The following are the consecutive steps in putting on the apparatus before entering a toxic atmosphere. ***The apparatus must always be put on in fresh air.***

1. Unfasten and straighten all harness straps.

2. With one hand, grasp the apparatus by the plunger casting, dropping the facemask over the hand holding the apparatus. With the other hand grasp the D-ring assembly and place the breast plate of the canister holder on the chest and slip the head through the opening formed by the two web straps.

3. Hold the apparatus on the chest with one hand and with the other reach around the body and grasp the free end of the web strap. Bring the end of the strap under the arm and snap into the D-ring located on the top side of the breast plate. Repeat this procedure for the other strap.

4. Adjust the position of the apparatus on the body. The position of the apparatus on the body should be such that when the facemask is put on, the breathing tubes will permit free head movement.

5. Attach the waist strap to the small D-ring located on the lower corner of the breast plate and pull up to a snug fit, tucking in the loose ends.

6. Pull out the facemask headband straps so that the ends are at the buckles and grip facemask between thumb and fingers. Insert chin well into the lower part of the facemask and pull the headbands back over the head. To obtain a firm and comfortable fit against the facemask at all points, adjust headbands as follows:
   (a) See that straps lie flat against head.
   (b) Tighten lower or ''neck'' straps.
   (c) Tighten the ''side'' straps. (Do not touch forehead or ''front'' straps.)
   (d) Place both hands on headband pad and push in toward the neck.
   (e) Repeat operations (b) and (c).
   (f) Tighten forehead or ''front'' straps a few notches if necessary.

   Test the facemask for tightness by squeezing the corrugated breathing tubes tightly. Inhale gently so that the facemask collapses slightly and hold breath for 10 seconds. The facemask will remain collapsed while the breath is held providing the assembly is gas tight. If any leakage is detected around the facial seal, readjust head harness straps. If other than facial seal leakage is detected, investigate the condition and correct. The facemask must be subjected to a tightness test before each use.

7. With the facemask adjusted and checked for tightness, start the canister by the following method.
   (a) Pull lanyard straight out away from body. Removal of cotter pin fires candle, inflating breathing bag with oxygen within 15 seconds.
   Note: If candle fails to fire, insert new canister.
   (b) Starting of the candle may be accompanied by a slight amount of harmless smoke. The breathing bag will be inflated with oxygen.
   After using do not attempt to reuse either type of canister.
   The ***Chemox*** apparatus should be stored and started at temperatures above 0°C. When a Quick Start Canister is used, the apparatus can be started at temperatures as low as -25°C.

8. To check the complete apparatus for tightness.
   (a) Grasp the lower end of the inhalation (left hand) breathing tube and squeeze it tightly. Inhale gently and if the facemask collapses, the facemask seal is sufficiently tight and the exhalation valve is functioning properly. This will also test the upper part of the inhalation breathing tube for leaks.
   (b) Continue to squeeze the lower end of the inhalation (left hand) breathing tube. Depress the pressure relief valve button, it should then be possible to exhale through the valve. While still holding the button down, inhale and if the facemask collapses as above, the relief valve is functioning properly.
   (c) Release the inhalation (left hand) tube and squeeze the lower end of the exhalation (right hand) breathing tube. Inhale and then exhale forcibly. The exhaled air should be forced out between the face and the facemask only, this will indicate that the inhalation valve is functioning

properly and the upper end of the exhalation tube is free of leaks.

(d) With the bag well inflated, grasp the upper ends of both breathing tubes and squeeze tightly, and depress both sides of the breathing bag with the elbows. ***If the breathing bag does not deflate, the complete apparatus is tight.***

If a leak or defect is indicated in any part of the apparatus, it should be checked and the condition corrected before use.

9. Breathe normally as the apparatus furnishes enough oxygen to meet any breathing requirement.

Use of the Timer

Since the apparatus has a nominal one hour service life as indicated below, it is necessary to determine the length of time required to return to fresh air from the working place and set the timer accordingly. The timer dial is calibrated in minutes, and by turning the pointer clockwise to the number of minutes left after deducting the time for exit, the timer will be properly set. For example, if it takes 10 minutes to return to fresh air, deduct 10 minutes from 60 and set the timer at 50. The bell on the timer will ring for approximately seven seconds when the pointer returns to zero, at which time the wearer must return immediately to fresh air.

Service Life

This equipment is approved by the U.S. Bureau of Mines as a "one-hour" unit. The duration of the unit will depend on factors such as:

1. The degrees of physical activity of the user;
2. The physical condition of the user;

3. The degree to which the user's breathing is increased by excitement, fear, or other emotional factors;

4. The degree of training or experience which the user has had with this or similar equipment;

5. The condition of the apparatus.

General Information for Use

The canister will produce more oxygen than will be used so the breathing bags will become over inflated, causing exhalation resistance. The excess volume can be eliminated (vented) by depressing the valve button on the facemask as required.

There are two indications in addition to the timer that the canister is becoming expended; fogging of the lens(es) on inhalation and increased resistance of exhalation. These two indications will not normally appear until after one hour of use but may become noticeable under conditions of extreme hard work. The lens(es) will clear on inhalation until the canister is almost expended, then they will begin to fog. Do not confuse excess breathing bag pressure with canister resistance. If excess breathing bag pressure is relieved by use of the pressure relief valve and the exhalation resistance is still present, the canister is almost expended.

If either of these two indications appear, return to fresh air.

Caution: Never allow any substance to enter the neck of the canister, such as water, oil, gasoline, and grease, as the chemical contains oxygen, which may cause combustion of any flammable materials.

General Information After Use

1. To remove the canister turn the handwheel down, swing bail outward and remove the canister with the hand suitably protected by a glove or other covering since the canister may be hot. ***Do not reuse the canister.***

2. Always use the following procedure before discarding the canister: To dispose of canister, punch a small hole in front, back and bottom, and place in bucket of clean water sufficiently deep to cover the canister at least three inches. When bubbling stops, any residual oxygen will be dissipated and the canister will be expended. Pour the residual water, which is caustic, down a drain or dispose of it in any other suitable manner and then discard the canister. ***Do not puncture canister underground.***

Cleaning and Sanitizing

The facemask and breathing tube assembly (disconnected from the apparatus by detaching coupling nuts) should be cleaned and sanitized after each use.

1. Immerse solid equipment in sanitizing solution and scrub gently with a soft brush until clean.
2. Rinse in plain warm water (about 50°C) and then air dry.

None of the metal, plastic, rubber, leather, cloth, or glass parts will be adversely affected by the cleaning solution.

The inhalation and exhalation check valves are removable from the facemask and breathing tube assembly by disconnecting the clamps, removing the breathing tubes and sliding the valves out. They should be checked periodically and cleaned or replaced if necessary. DO NOT remove the valve from its seal during cleaning. This will prevent improper reassembly. Dry valves thoroughly after cleaning. Replace each valve assembly in the side from which it was removed. Each valve assembly and housing is indexed with ridges and slots for correct replacement.

While the apparatus is not in use, there should be a periodic check of the plunger and plunger casting (the part which pierces the canister) for cleanliness and free movement of the plunger. The tightness of the apparatus should also be checked

periodically using the procedure outlined in donning of apparatus.

When any part shows evidence of failure, it should be replaced immediately with a new part. Apparatus which becomes damaged should be returned to the factory for repair.

Storage

When not in use the apparatus should be kept in the carrying case provided and canisters should be stored in a dry place.

Demand Apparatus

Scott Air Pak | MSA Air Mask

Demand apparatus describes a breathing apparatus that will deliver air as required by inhaling it. It does not supply a constant flow or circulate the air for re-breathing. Demand apparatus in Ontario mine rescue is restricted to the use of pure breathing air.

Due to the restrictive time limit of Demand Apparatus, Ontario mine rescue developed a method of recharging the apparatus while wearing it in irrespirable atmosphere. This method involves the use of a charging hose assembly and a cylinder of air. Whenever it is necessary to wear a Demand Apparatus, the cylinder and charging assembly should accompany the wearer if the total distance of travel exceeds 200 metres in contaminated air from either a fresh air base or cylinder and charging assembly.

Scott Air Pak

The Scott Air Pak is a self-contained open-circuit apparatus and may be used safely in an atmosphere containing any gas except those which irritate or poison through the skin such as hydrogen cyanide or highly concentrated ammonia.

Model No. 6000 A2M was approved by the U.S. Bureau of

Mines for 30 minutes of continuous use with a fully charged air cylinder having a capacity 40.3 cu. ft. (1,141 litres) at a pressure of 1,980 psi (13,700 kPa). Its total weight is 13 kg (29 lb.).

The Scott Air Pak II also has a 30-minute approval and differs only in the design of the regulator and the pressure rating of the cylinder. This newer style regulator delivers a greater litre flow of air on demand with less inhalation resistance. The cylinder may be pressurized to 2,215 psi (15,400 kPa) giving approximately 45 cu. ft. (1,275 litres).

The purity of the air used to recharge Air Pak bottles is of prime importance as the compressed air must contain not less than 20 per cent of oxygen and not more than 5 ppm carbon monoxide. Air compressors using oil lubrication may be used as a source of compressed breathing air only when carbon monoxide indicating devices are used in the circuit continuously to check the purity of the air. Moisture and organic vapour filters must also be used before the air is delivered to the apparatus cylinder.

Parts of the Apparatus

The Scott Air Pak has five main parts:

1. A bottle containing pure breathing air;
2. a reducing valve and demand regulator with a shut off valve and a bypass valve;
3. a facemask and corrugated breathing tube with a "quick-connect" coupling;
4. a metal back plate to which is fastened the web-type carrying harness;
5. an auxiliary charging hose and the female half of a high pressure self-sealing coupling. A low pressure alarm is an auxiliary part of the apparatus.

Air Cylinder or Bottle

For the purposes of clarity the term "bottle" will be used throughout this description. The bottle is made of a metal alloy and is much lighter than a steel bottle of comparable size. It is approved by the U.S. Interstate Commerce Commission and tested to a pressure of 3,000 psi (21,000 kPa). When charged to its present permitted pressure of 1,980 psi (13,700 kPa), it contains 40.3 cu. ft. of air (1,141 litres).

The newer Air Pak II cylinder may be charged to 2,215 psi (15,300 kPa) with 45 cu. ft. (1,275 litres) of air. The bottle valve incorporates a safety cap which will rupture at 3,000 psi (21,000 kPa) and a gauge which registers the bottle pressure at all times. This valve should be opened at least one complete turn when the Air Pak is being worn.

Low Pressure Alarm

An alarm bell is incorporated in the Scott II and is available for the 6000 A2M; it will ring when the bottle pressure is reduced to approximately 400 psi (2,800 kPa). This bell will continue to ring for 4 to 5 minutes until the bottle is emptied or recharged.

Reducing Valve and Regulator

The Scott Demand type Regulator delivers air to the user in accordance with his requirements. When the user inhales, the regulator delivers air reduced to a pressure of 3.5 psi (24 kPa) above atmospheric pressure during the inhalation period and in a volume dependent upon the inhalation. This flow may reach a maximum of 340 litres per minute. When the user exhales, the regulator shuts off the air from the bottle, thus conserving the air supply.

The regulator assembly consists of:

1. the regulator body and mechanism,
2. the high-pressure gauge,

Fig. 48 — Scott Air Pak II in Carrying Case

3. the bypass valve,
4. the regulator shut off valve,
5. the shut off regulator lock, and in the Scott Air Pak II, the low pressure alarm.

The high pressure gauge is mounted on the regulator housing in view of the wearer at all times. This gauge indicates the bottle pressure when the main bottle valve is opened and provides a positive indication of the amount of air left in the bottle. The markings on the dial are luminous for maximum visibility.

The assembly is connected to the flexible hose from the bottle and fastened to the chest strap of the harness. The regulator is connected to the breathing tube from the facemask by a "quick connect" coupling. The regulator shut off valve (yellow knob) is provided to shut off the air to the regulator.

A bypass (red knob) valve is provided for use in the event of a faulty demand regulator assembly.

Operation of the Regulator

Air at bottle pressure enters the regulator at (A), passes through shut off valve orifice (B), and continues through passage (C), through screen (D), and orifice (E). After being reduced by first stage valve (F) to a lower pressure, the air continues past it to the inside of bellows assembly (G), which is spring-loaded to maintain a constant pressure of 35 psi (250 kPa) in this chamber. If this pressure increases, the bellows expands, actuating lever (H), which in turn closes first stage valve (F), reducing the pressure. If the pressure in the bellows drops, the reverse takes place, maintaining the pressure in the bellows chamber at 35 psi (250 kPa). The air now flows through passage (I) to demand valve (J) *(See Fig. 50)*.

When the user inhales he creates a suction in the facemask and breathing tube assembly to chamber (L). When the pressure in chamber (L) is reduced, the outside atmospheric pressure depresses diaphragm (M) inward, moving demand valve stem (N) toward its open position. The demand valve then opens, permitting the air to flow from passage (I) and under the diaphragm. Since the area of diaphragm (M) is large and the spring resistance of the demand valve is low, the suction

required for full opening of the demand valve is small. The variation in effort in breathing is not noticeable, regardless of whether the user is at rest or performing physical exertion.

Orifice (E) is protected by inlet screen (D) which has a total area of openings of over 15 times that of the normal orifice opening. This provides adequate protection against any clogging of orifice (E) which may restrict the flow to less than maximum requirements.

Fig. 49 — Scott Air Pak Showing General Arrangement of Harness, Recharging Hose, and Two Types of Facemask

If first stage valve (F) sticks in the open position, permitting pressure in passage (I) to build up beyond 50 psi (350 kPa), safety valve (O) opens, discharging air in a continuous flow, at reduced pressure, directly into chamber (L). Under such circumstances, the user would be warned that the initial

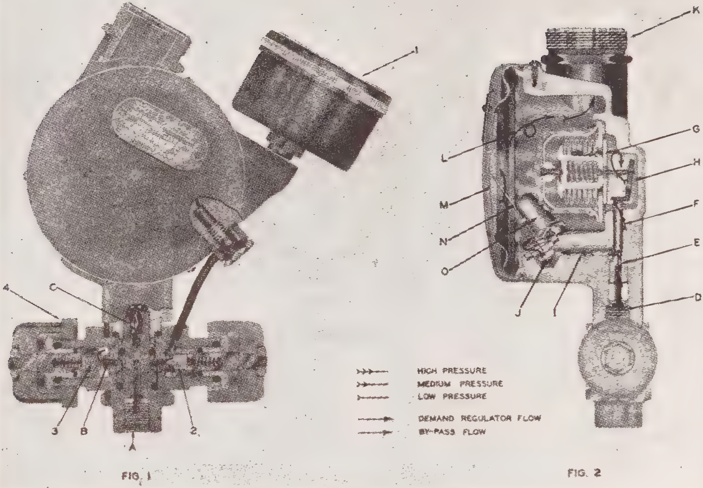


Fig. 50 — Diagram of Air Flow Through Scott Air Pak Regulator

reduction stage had failed. He would receive a continuous flow of air to the mask at an increased pressure. He should return to fresh air at once. It is almost impossible for valve (F) to stick in the closed position because the high pressure is applied to the underside of the valve. This would force the valve open under any conceivable condition.

Should demand valve (J) stick in the open position the flow of air through restricting orifice (E) would so limit the volume that there would only be a tendency to inflate the facemask, and the pressure in the mask would be held at less than 7.5 cm (3 in.) of water by the operation of the exhalation valve.

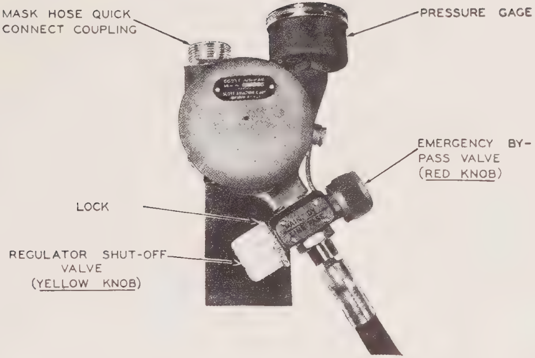


Fig. 51 — Scott Air Pak Regulator

Fig. 52 — Scott Air Pak II Regulator

Facemask and Breathing Tube

Facemasks available for the Scott Air Pak are full face, full vision type. A rubber diaphragm exhalation valve in front of the wearer's mouth permits talking or telephoning. Air is inhaled through a corrugated rubber tube connected to a Y-shaped fitting at the bottom of the facemask. Each branch of the Y leads to the bottom of the lens. The inhaled air flows over the lens and clears off any fogging that may occur. The facemask is held tight to the face by quick adjusting headstraps.

The bottom end of the breathing tube has a fitting which enables the user to connect or disconnect the breathing tube easily and quickly, using his fingers only.

Harness

The harness is made of a specially treated webbing. The metallic snaps and buckles are treated to reduce sparking.

The harness consists of a back plate under the bottle, two shoulder straps, a chest strap, and a waist strap. At the top of the back plate is a D-ring for attaching a safe line.

Charging Assembly

An advantage of this type of apparatus over other types of breathing devices is the ability to recharge the bottle when wearing the apparatus in an irrespirable atmosphere.

The charging hose assembly is connected to the T-fitting at the bottle valve connection; a pressure operated check valve is connected between the T-fitting and the charging hose to prevent air escaping from the bottle when the charging hose assembly is not in use.

The high pressure hose is about 24 in. (61 cm) long, with the female half of a high pressure self sealing coupling attached (the male portion of this coupling has the self sealing valve in it). When not in use the apparatus charging hose assembly is fastened to the chest strap on the right hand side.

Directions for Operating the Scott Air Pak

During normal operation of the apparatus, the shut off valve (yellow knob) should be fully opened and locked in position. It is provided to shut off the operation of the demand regulator in the event of damage or failure and should be closed only after the

Fig. 53 — Front View of Man Wearing Scott Air Pak II

bypass valve has been opened. The emergency bypass valve (red knob) should be fully closed. It is provided for use in case the automatic demand regulator becomes inoperative. When opened it provides a continuous flow of air to the facemask by passing the regulator mechanism. If required, the bypass valve should be opened first, by turning counter clockwise, then the regulator shut off valve should be closed and the flow of air through the bypass valve adjusted to suit the user's requirements.

When operating the valves, turn firmly with the fingers. Do not use force.

Tests for the Scott Air Pak

Similar to all other breathing devices the Scott Air Pak should be frequently tested between periods of actual use (at least once a month) to determine its condition, and should always be carefully tested for air tightness and proper working order before it is worn. Any leaks and/or defective parts found during these tests should be adjusted, repaired or replaced. There is absolutely no excuse for wearing a breathing device that is known to be defective.

When soapsuds have been used for detection of leaks the parts should be thoroughly cleansed after the test has been completed. Any repairs or adjustments necessary to the regulator must only be done by the manufacturer, his agent or by a person authorized to make such repairs by the Director, Mining Health and Safety Branch.

Station Tests

Harness

Check the equipment to see if it is complete, paying attention to the harness. See that no undue weakening has taken place through wear or chafing especially where the webbing passes

through the back plate and where the regulator loop fastens over the chest strap.

Testing Bottle

Test for moisture in bottle. After the bottle has been charged, hold it in a vertical position with the valves down. Open the main bottle valve and close it quickly. If vapour is blown from the valve it shows that moisture is gathered in the bottle. Accumulations of moisture, sediment, rust, or scale should be removed by taking the valve out of the bottle and cleaning the bottle.

Fig. 54 — Back View of Man Wearing Scott Air Pak

Test for tightness of bottle valve. To test the main bottle valve, firmly attach a metal cap, with the gasket provided for this purpose, to the outlet end of the valve under test, making sure that the bottle is fully charged, and open the valve to its fullest extent. Immerse the valve and neck of the bottle in water. Escaping bubbles around the valve stem indicate a leak in the packing gland. Close the main bottle valve, remove the metal cap and again immerse the outlet of the valve in water. Bubbles indicate that the valve is not closed tightly or that it has a defective seat. Any leaks or defective parts found during either test should be repaired or replaced before the bottle is used.

All steel and aluminum air and oxygen bottles, must be retested every five years to comply with the regulations of the Canadian Transport Commission. Composite bottles have a different test schedule, usually requiring testing every three years.

Test for Regulator and Regulator Hose Assembly

With the equipment connected (except facemask and breathing tube), open the bottle valve and observe the bottle gauge pressure. Observe the pressure of the gauge mounted on the regulator housing. The two gauges should check. Close the main bottle valve. The regulator and regulator hose assembly should hold the trapped pressure. Should a drop in the pressure be shown by the needle of the regular gauge moving back toward zero, a leak is indicated.

Regulator Shutoff Valve — Yellow Knob

With the regulator shut off valve and by pass valve closed and the main bottle valve open, draw air in from the "quick connect" orifice by inhaling until the regulator gauge is at zero. Then watch the gauge to see if the pressure builds up. If the pressure rises, the regulator shut off valve is leaking.

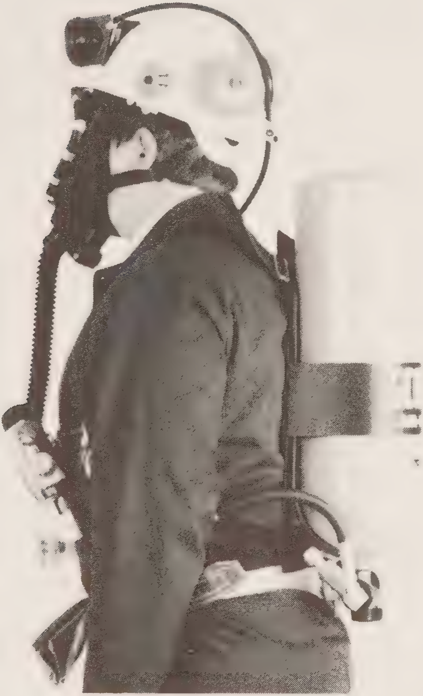


Fig. 55 — Left-Side View of Man Wearing Scott Air Pak II

Bypass Valve — Red Knob

With the regulator shut off valve and bypass valve closed and the main bottle valve open, place a soap bubble across the "quick connect" fitting on the regulator. If the bypass valve is leaking, the bubble will expand and break.

Charging Hose Assembly

With the main bottle valve open remove the dust cap from the end of the charging coupling, immerse the end of the coupling in water. Any bubbles will indicate a leak in the pressure operated check valve. Check the connection by means of a soap and water solution. A leak in the hose may be found by immersing the hose in water.

Facemask Test

Put on the facemask and tighten the straps on the head harness; seal the bottom of the breathing tube with the hand, inhale, and hold the breath as long as possible. Do this several times. If the facemask or the breathing tube appears to leak, check the fitting on the face and, if the leak is still indicated, locate it or replace the facemask and the breathing tube.

General Test

With bottle valve open and wearing facemask inhale deeply and quickly. The regulator should supply a full flow to give the user, on demand, all the air he requires.

If, during slow light inhalation a ''honking'' or ''chattering'' sound is heard in the regulator, it can usually be stopped by breathing faster. If the bellows vibrate under any breathing condition, the regulator should be changed.

If the demand valve sticks in the open position, air will continue to flow when the user is not inhaling. This condition can usually be corrected by blowing back into the regulator.

Field Tests

The Field Tests are to be carried out by the user each time the apparatus is worn, before leaving the fresh air base. Check the general condition of the apparatus paying particular attention to the harness.

High Pressure Test

1. Remove everything from case and place on table, bottle valve away from you.
2. Examine harness and recharge hose (tightness of dust cap).
3. Check bottle gauge for full air bottle.
4. Open bottle valve; bring regulator gauge over and compare both gauges.
5. Close off bottle valve and observe regulator gauge for an indication of a leak (minimum 15 seconds).
6. Open bypass valve, reduce pressure to approximately 400 psi (2,800 kPa) and warning bell should ring; close off bypass valve.

Facemask Test

1. Examine facemask and breathing tube for damage, deterioration.
2. Check O-ring gasket and connect breathing tube to regulator.
3. Put on facemask.
4. Inhale to check facemask seal and diaphragm for leaks.
5. Open bottle valve one full turn.

Regulator Test

1. Inhale deeply three times, checking function of demand valve and exhalation valve on facemask.
2. Remove facemask and set on bench (complete apparatus now laying on the bench)
3. Report the results to the team captain who will give instructions when the apparatus is to be worn.

Scott Air Pak With Extension Hose

The equipment consists of a standard Scott Air Pak equipped with an auxiliary connection in the air supply line between the apparatus bottle and the regulator, and cylinders of compressed air equipped with a special supply hose. *(Fig. 59).*

A person may travel in an irrespirable atmosphere, using air from the apparatus bottle to a place where there is an auxiliary supply of compressed air. Here he may recharge his apparatus bottle from a large cylinder by equalization, or obtain air directly from the large cylinder. A 244 cu. ft. (6.8 m^3) cylinder, at 2,200 psi. (15,200 kPa), will supply the user under normal conditions for a minimum of 6 hours. A ''jumbo'' size cylinder, with a capacity of 300 cu. ft. (8.5 m^3) at 2,400 psi. (16,500 kPa) gauge pressure will supply the user for a minimum of 8 hours.

The complete Scott Air Pak, with extension hose assembly, consists of one or more large cylinders of air at the desired location with suitable manifolds if necessary; a ''T'' connection equipped with a pressure gauge; a high-pressure extension hose of the desired length equipped with the male half of a pressure operated quick connect coupling.

The wearer may leave the fresh air base wearing this apparatus and, on arrival at the work's site, while still breathing from the apparatus, may recharge his bottle by connecting the coupling of his apparatus to the coupling on the hose of the recharge assembly. The following steps must then be done in order.

1. Open the valve on the large cylinder to recharge the apparatus bottle by equalization.
2. Close the valve on the apparatus bottle.
3. Leave the couplings connected and the valve of the large cylinder open. This will enable him to breathe directly from the large cylinder for an extended period, and still have a full bottle for retreating to surface.

Fig. 56 — Checking Bottle and Regulator Gauges for Pressure

When the operator is ready to return to the fresh air base he should open the valve on the apparatus bottle, close the main valve on the large cylinder, disconnect the coupling of the extension hose, and proceed to fresh air.

Fig. 57 — Separately Testing Facepiece of Scott Air Pak II

Demand Apparatus Cascade Recharge System

The success of the Demand Type apparatus in mine rescue work depends on the ability of the wearer to recharge his bottle without removal even though he is in an irrespirable atmosphere. This is done by taking to the working place, or, some place ahead of the fresh air base and as near the working

Fig. 58 — Man Testing Apparatus for Air Tightness, Bottle Valve Closed.

face as possible, several cylinders of air compressed to a pressure of 2,400 psi. (16,500 kPa), each cylinder when fully charged having a capacity of 300 cu. ft. (8.5 m^3) of free air; a suitable manifold for connecting two, three or more cylinders together; a charging hose assembly consisting of a coupling for connecting to the cascade manifold; a high pressure gauge; a

suitable length of flexible high pressure hose and the male half of a pressure operated self-sealing coupling, the female half of this coupling being a part of the apparatus worn by the user.

Method of Cascading

As the usual number of cylinders used for recharging bottles will be three in number this will be used as an example and standard throughout these instructions.

The first rescue team to go into a working place will transport with them the large cylinders to set up a cascade station ahead of the fresh air base. The cylinders are connected together by means of high pressure couplings which consist of a T-fitting, a pressure operated check valve and either a metal tube or a high pressure flexible hose and a charging hose assembly.

The charging hose assembly consists of one self-sealing coupling whereby the team can recharge their bottles one at a time or, a manifold having several charging hose assemblies.

The charging hose assembly is always to be connected to the extreme left hand cylinder and the cylinders opened in turn from the extreme right. The cascading will always be counter clockwise, so that the right hand cylinder will always have the lowest amount of air in it, the next cylinder having the second lowest reading and the one on the extreme left being full or nearly so.

When the team captain sees that the lowest reading of any of the bottle pressures is double the amount required to reach the cascade station he will order the team to return for recharging.

The team will proceed to the cascade station. When he arrives at this station each man will, without waiting for further orders, unfasten his charging hose from the chest strap. When there is only one charging hose, the man with the lowest reading will step forward and connect his charging coupling to that on the cascade. The team captain will then open the right hand cylinder valve and when the pressure in the gauge on the apparatus

corresponds to the pressure shown on the gauge of the charging assembly of the cascade he will close that cylinder valve and open the cylinder valve on the next cylinder. The process is repeated and when the guages have again equalized, that cylinder valve is closed and the bottle topped off from the last cylinder.

Fig. 59 — Man Wearing Scott Air Pak II With Large Cylinder and Flexible Extension Hose.

When more than one charging assembly is connected to the cascade the procedure is the same except the team captain will check all the gauges of the apparatuses connected to the cascade system. This is repeated until all team members have recharged their bottles.

Great care must be exercised by the team captain and the man wearing the apparatus that:

1. the recharging operation starts from the lowest cylinder,
2. the pressure shown on the gauges of the cascade system and the apparatus finally correspond;
3. equalization is complete before closing the main cylinder valve and opening the next valve.

If after using the last cylinder in the cascade system the bottle is still not fully charged a full storage cylinder should be put into the cascade system. This is done by disconnecting the cylinder with the lowest pressure and removing it from the cascade system and putting the fully charged cylinder on the extreme left of the circuit.

It is the responsibility of the team captain to check the cascade immediately after being set up for correct sequence, functioning of check valves and tight connections.

MSA Air Mask

The MSA. Air Mask, *(Fig. 60)* is a self-contained breathing apparatus approved for use in toxic or oxygen deficient atmospheres. Its outward appearance may differ from the previously described apparatus, but the procedures of testing and wearing and its function are similar.

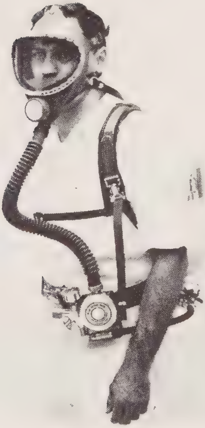


Fig. 60 — MSA Air Mask

Parts of the Apparatus

There are five main parts:

1. a bottle with a capacity of 45 cu. ft. (1,275 L) of pure breathing air;
2. a demand regulator containing a shut off valve, a bypass valve and a pressure gauge;
3. a high pressure hose with installed low pressure "Audilarm", connecting the demand regulator to the bottle;
4. a facemask assembly with built-in speaking diaphragm;
5. a light metal frame on which the bottle is mounted, a nylon harness resistant to water and chemicals, and "Cushionaire" shoulder straps.

Fig. 61 — Man Recharging MSA. Air Mask With "Wear-N-Fill, Stand-N-Fill"

In addition, a system called "Wear-N-Fill, Stand-N-Fill" is available, whereby the bottle of the apparatus may be recharged while being worn in a contaminated atmosphere. The

''Wear-N-Fill, portion is permanently connected to the apparatus and consists of a T-block, check valve, high pressure hose and the male half of a quick connect coupling. The ''Stand-N-Fill'' portion is attached when in use to the supply cylinder, and consists of the desired length of flexible high pressure hose and the female half of a quick connect coupling *(Fig. 61)*.

The application and method of use of the ''Wear-N-Fill, Stand-N-Fill'' is identical to that described earlier in this text. Both systems are ideal and are recommended for use by winze hoistmen or cage tenders during a mine fire.

Fig. 62 — Man Wearing Drager OXY-SR45 Self-Rescuer

Drager Oxygen Self-Rescuer—Model OXY-SR 45 M

The OXY-SR 45 M is a self-contained, closed-circuit oxygen breathing apparatus, which provides the wearer with breathing protection, entirely independent of the surrounding atmosphere for approximately forty-five minutes if fully charged to 4,410 psi (30,000 kPa). If the cylinder is charged to 3,000 psi (21,000 kPa) the time limit will be reduced to 20-30 minutes.

Description of Components

The plastic case contains an oxygen cylinder, a regenerative canister, a breathing bag, an oxygen control assembly partially inserted into the bag, and a facemask and breathing tube.

1. The oxygen cylinder when charged to a pressure of 4,410 psi (30,000 kPa) contains about 65 litres. The cylinder valve is operated by a turn type lever and is equipped with a pressure indicating gauge.
2. The regenerative canister filled with 1.2 lb (.5 kg) of soda lime chemical is fitted with upper and lower screens. The top screen is held in place by a tension spring under a retaining ring fitted over the top of a central tube which is inserted through the bottom of the apparatus. The cover of the canister contains two one-way valves to control the circulation of oxygen.
3. The breathing bag is made of tear resistant rubberized fabric, with a capacity of 4.2 litres when fully inflated. The bag is fitted with reinforcing plates for the operation of the lung controlled demand valve. The pressure relief valve is placed in the side of the bag so that if the bag becomes over inflated the valve opens in contact with the side of the case, permitting excess pressure to escape. A non-return check valve prevents the entrance of outside air.

4. An oxygen control assembly is held partly within the breathing bag by a tight fitting rubber collar over a double flanged fitting. It consists of a miniature reducing valve, a constant flow metering device which delivers oxygen into the system at the rate of 1.2 litres per minute, and a lung controlled demand valve. This assembly is attached to the oxygen cylinder by a finger tight connection.

5. The facemask is made of pliable rubber and is fitted with splinter proof lens. The breathing tube is attached to a plastic cover that fits on top of the soda lime canister.

General Use

Open the case. Remove the facemask which is folded in the cover. Unfold the breathing bag, check the pressure on the gauge and open the cylinder valve. Press the reinforcing plate in the side of the bag against the demand valve until the breathing bag is nearly full. Remove the plug from the facemask end of the breathing tube and adjust the facemask on the face. Squeeze the breathing tube and try to inhale to test the seal around the face.

Field Tests

The field tests are to be made by the user each time the apparatus is to be carried.

Following is the order in which the tests are made:

1. Examine the harness and case for damage.
2. Break the seal and open the case.
3. Check the gauge for a full bottle.
4. Remove the facemask from the lid and inspect thoroughly.
5. Unfold the breathing bag and inspect.

6. Open the bottle valve. Check for a stuck demand valve (If the valve is stuck oxygen will blow off, so bottle valve must be closed immediately).
7. Check the operation of the demand valve — briefly trip valve once.
8. Close off the bottle valve.
9. Remove the plug from breathing tube inside facemask.
10. Exhaust oxygen from breathing bag, fold and repack.
11. Replace plug into top of breathing tube (inside mask).
12. Repack facemask in lid, close and latch case.
13. Report the results to the team captain.

Circulation of Oxygen

The exhaled breath flows down the single breathing tube, and through the soda lime, where the carbon dioxide is removed. The purified air then passes up through the central tube into the breathing bag where it is joined by oxygen being delivered from the constant flow metering device. On inhalation the air in the breathing bag passes through the one-way valves in the valve chamber and into the breathing tube. Should the flow of 1.2 litres per minute be insufficient for the wearer, the breathing bag will gradually deflate and the plate in the side of the bag will be pressed against the demand valve causing it to open, delivering an adequate supply of oxygen to the wearer. Should the bag become over inflated the pressure relief valve will be pressed against the side of the case causing it to open and release the excess pressure to the outside atmosphere.

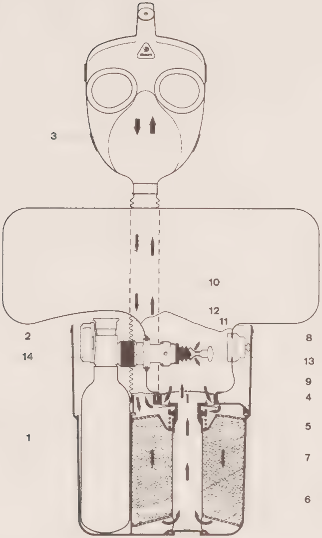


Fig. 63 — Diagram Showing Circulation of Oxygen in OXY-SR 45.

Recharging the OXY-SR 45 M

Remove the oxygen cylinder and recharge. Loosen the screw coupling on the bottom of the case with the wrench provided, until the breathing bag and regenerator cover can be removed. Remove the oxygen control assembly from the bag. Detach the breathing tube from the cover by loosening the clamp. Remove the retaining ring by pressing it down and turning it until it is free. Lift the cover from the regenerative canister and empty the soda lime. The central tube should be removed and the entire unit except the oxygen control assembly, washed and sterilized. After the parts are thoroughly dried, the apparatus may be reassembled, using approximately 1.2 lb. (.5 kg) soda lime chemical to refill the regenerator.

Station Tests of the OXY-SR 45 M

Leak Test

Place a test cylinder in the apparatus and connect to the Universal Tester using the connecting tube and facepiece adapter. Set the tester to "Negative Pressure Pumping" and empty the bag until the pointer rests between -80 and -100 mm. Set the tester to "Leak Test" and adjust the pointer at -70 mm H_2O by depressing the red button briefly. If the needle does not drop more than 15 mm in one minute the apparatus may be considered satisfactory.

Dosage Test

With the apparatus still attached to the Universal Tester, place a small plastic cap or a nut over the button of the relief valve to prevent it being opened during this test. Open the cylinder valve, set the testing unit at "Dosage" then press the side of the bag against the demand valve until the bag is almost fully inflated. Watch the pointer on the tester, it should read between 1.15 and 1.45 when using a fully charged cylinder.

Testing the Relief Valve

Remove the cap over the button of the relief valve, set the testing unit to "Leak Test". Watch the positive pressure at which the needle stops. This is the pressure required to open the relief valve. It should open between +20 and +60 mm.

Testing the Demand Valve

Set the testing unit to "Negative Pressure Pumping" and slowly operate the pump until the demand valve is heard to open. This should occur between -10 and -40 mm.

Positive Pressure Leak Test

Place the cap over the relief valve. Set the tester to "Positive

Pressure Pumping'' and inflate the bag until the needle rests between +80 and +100 mm. Set the tester to ''Leak Test'' and adjust the needle at +70 mm. If the needle does not drop more than 15 mm in one minute the apparatus may be considered satisfactory. Remove the cap from the relief valve and repack the unit.

Note: OXY-SR 45 apparatus maintained at all Ontario mine rescue stations are intended to be used for emergencies only. One or two units will be opened and used for training mine rescue teams in its use. The remainder will be retained in a sealed condition, ready for immediate use.

Station Tests described previously will be conducted on each OXY-SR 45 at three-month intervals by the Mine Rescue Officers and then resealed.

Two OXY-SR 45 apparatus will be carried as emergency equipment by each mine rescue team during a mine fire. Additional units may also be carried for the purpose of evacuating trapped miners through hazardous gaseous atmospheres.

Portable Air Supply Systems (PASS)

An approved 60-minute self-contained apparatus, PASS Model 700E, developed for self rescue purposes, provides the user with a one-hour supply of oxygen for emergency use.

Description

The unit is a closed-circuit compressed oxygen breathing apparatus with refillable oxygen bottle and replaceable regenerative cartridge. It is equipped with either facemask or mouthpiece and may be used as a self rescuer and by mine rescue teams as auxiliary equipment.

Main Parts

1. 240 litre oxygen bottle at 2,000 psi;
2. replaceable regenerative cartridge;
3. constant flow oxygen regulator;
4. facemask and hoses;
5. plastic breathing bag;
6. harness and shock resistant case.

Operating Instructions

The apparatus is stored in a protective carrying case and when removed is ready for instant use. Pulling a start valve activates an immediate flow of oxygen into the breathing bag. Once started, the unit cannot be shut off, preventing only partial usage. The constant flow oxygen supplements the regenerated exhaled breath in the closed-circuit system.

Once activated, the facemask is put on and the wearer is provided complete respiratory protection.

Return to fresh air immediately.

Questions on Chapter IV

1 **What procedure should be followed to insure the demand type apparatus will be ready for instant use?**

A full bottle should be in the apparatus at all times and the main line valve should always be left open to prevent the possibility of an attempt to use the apparatus with the oxygen supply shut off.

2 **What is the maximum allowable pressure for filling demand apparatus bottles?**

These bottles can be filled to 2,200 psi., (15,200 kPa).

3 **May compressed air from any source be used to refill air bottles?**

No. Only air that is certified to be pure should be used.

4 **What tests should be made with any breathing apparatus before entering a toxic atmosphere?**

The field tests must be made by the individual wearer.

5 **What should be done if the air supply is cut off while wearing demand apparatus?**

Open the emergency bypass valve, regulate the flow of air, and return to fresh air immediately.

6 **Name the six main parts of the Drager BG 174.**

7 **Describe the procedure when testing a Type N Mask before wearing it.**

8 **What use may be mde of the OXY-SR 45 apparatus?**

9 **What is the time limit of the OXY-SR 45 when the cylinder is charged to (a) approx. 4,400 psi. (30,000 kPa) and (b) approx. 3,000 psi (21,000 kPa)?**

Chapter V

Auxiliary Equipment to Drager BG 174 Apparatus

Drager Universal Tester, Model Rz 25

The Universal Tester is a multi-purpose unit for use in the testing of the Drager BG 174 Oxygen Breathing Apparatus and other similar types of breathing equipment.

When used for testing the BG 174, the tester will perform the following functions (as explained in detail under "Field Tests" and "Station Tests", Chapter IV);

1. Negative leak test
2. Operation of Automatic demand valve
3. Operation of constant flow metering orifice
4. Positive leak test
5. Operation of relief valve
6. Operation of warning signal

Drager Rz 35 Leak Tester

The Rz 35 Tester is a compact unit that may be used for the negative pressure testing of Drager BG 174 Breathing Apparatus as in Field Test No. 3. An aspirator bulb with rubber tubing attached is used to exhaust the air from the apparatus during the test. Mouth aspiration may be applied to the tubing as an alternative means of exhausting the air.

The Tester is a precision measuring instrument and should be handled and used with care. Careful handling will assure a proper test and a minimum of maintenance.

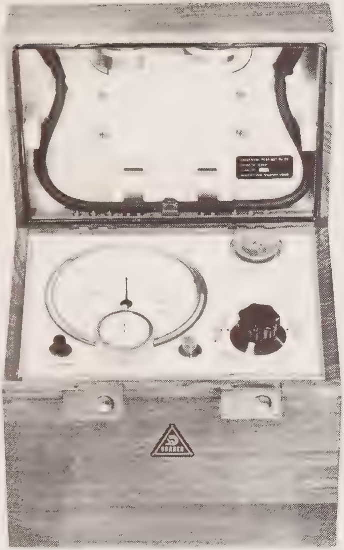


Fig. 64 — Rz 25 Universal Tester

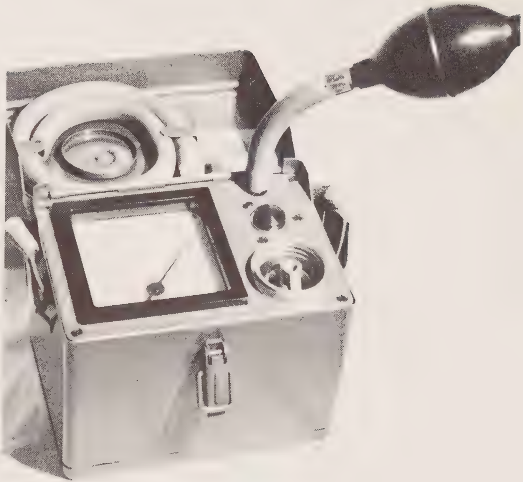


Fig. 65 — Rz 35 Negative Leak Tester

High Pressure Oxygen Booster Pumps

No oil or grease of any kind should be used in any type of high pressure oxygen pump. Chemical action between the oil or grease and the oxygen is possible and is very likely to result in a violent explosion.

The following pumps are multi-valve piston type pumps for compressing oxygen and transferring it from one cylinder to another at a desired higher pressure. Pumps are available in either hand operated or power driven types.

Drager High Pressure Oxygen Pump U200 or U300

This unit is a two cylinder pump capable of boosting the pressure in the cylinder being charged to either 2,000 psi (14,000 kPa) or 3,000 psi (21,000 kPa), according to the setting of the automatic control. ***The 3,000 psi (21,000 kPa) setting may be used only when charging Drager BG 174 or OXY-SR bottles.***

The level of the lubricant in the reservoir of the Drager pump must always be visible in the glass gauge tube on the end of the reservoir. During pumping operation, the circulating lubricant must be observed in motion beneath the two plastic domes on the console.

The lubricant mixture should be in the ratio of one part glycerine to four parts water.

Complete operating and maintenance details are described in the manufacturer's pump manual.

Charging Apparatus Bottles by Equalization

A system has been adopted whereby small apparatus bottles may be recharged by equalizing their pressure with that of large cylinders. A manifold has been designed to be connected to two or three large cylinders as shown in *Fig. 70*.

Fig. 66 — Drager Oxygen Pump With Bottle Connected

Upright cylinders should be chained or fastened to prevent their falling over.

Arrange the cylinders so that the one with the lowest pressure is to the right as you are facing them and the one with the highest pressure is on the left. Connect the rigid inlet coupling of the manifold to the centre one of three cylinders, and attach flexible hoses to the outer cylinders. A special coupling containing a filter is used to connect the small bottle being filled to the manifold. Care must be taken to see that the oxygen flows in the

Fig. 67 — Drager Oxygen Pump, Control Panel

direction of the arrow on the filter.

To recharge the small bottle, the following procedure must be adhered to:

1. Open the main bottle valve on the small bottle.
2. Open the valve on the right hand cylinder, and close it again as soon as all sound of the flow has stopped.
3. Repeat with the valve on the centre cylinder.
4. If necessary, repeat with the third cylinder.

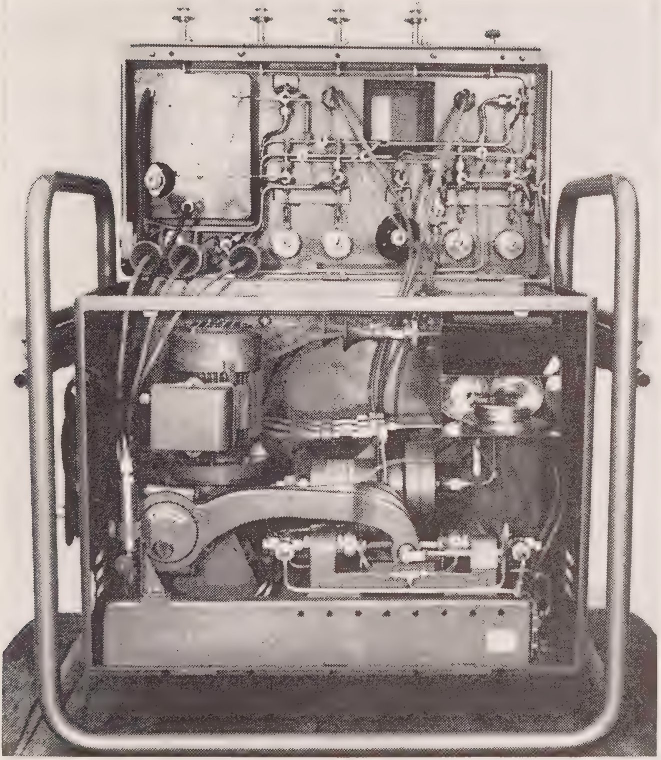


Fig. 68 — Drager Oxygen Pump, Covers Removed

5. Close the bottle valve, the main adaptor valve and the large cylinder valve. Open the bleeder valve on the adaptor and disconnect the bottle.

All valves should be opened slowly to prevent excessive heat generation and while doing so, pressure gauges must be observed.

If only two large cylinders are available, remove the hose on the left side of the manifold, and close off the opening with the cap attached to the manifold. The same recharging procedure should be followed.

Haskel High Pressure Oxygen Booster Pump

This unit is a two-stage air operated oxygen booster pump, capable of boosting the pressure in the cylinder being charged to as high as 4,450 psi (30,500 kPa) according to the setting of the automatic control. This is a fully portable unit, but should be operated by trained personnel following the manufacturer's operating and maintenance instructions.

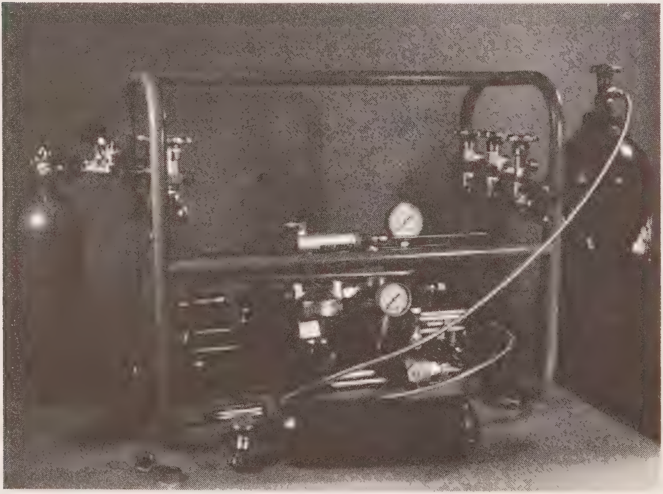


Fig. 69 — Haskel High Pressure Oxygen Booster Pump

Oxygen and Oxygen Cylinders

The purity of the oxygen used in rescue apparatus is very important, as impurities tend to accumulate in the circulatory system of the apparatus. For this reason any apparatus or equipment using compressed air supplied by oil lubricated compressors should not be converted to oxygen use without cleansing and purging. The U.S. Bureau of Mines specifies that oxygen for use in rescue apparatus shall contain at least 98 per cent of oxygen, no hydrogen; and not more than 2 per cent of nitrogen, with traces of argon. Oxygen made by liquefaction processes conforms to this standard and contains no impurities other than nitrogen, with traces of the rare inert gases.

All cylinders used to transport oxygen and other non-liquefied gases whose pressure exceeds 300 psi (2,100 kPa) at 21°C must comply with the requirements of the Canadian Transport Commission as to strength, and all such cylinders which exceed 12 in. (0.3 m) in length must have valves equipped with an approved safety device (bursting disc).

Cylinders that have an outside diameter of 2 in. (5 cm) or more must be tested by hydrostatic pressure at least once every five years and the date of testing must be marked on the cylinder as required by the Canadian Transport Commission. Composite bottles have different test schedules requiring more frequent testing.

The tests consist of determining the "elastic expansion" (total expansion minus permanent expansion) when the bottle is subjected to a hydrostatic pressure.

It will be noted that the oxygen bottles, which are usually charged at about 135 atmospheres, are tested at 3,000 psi (21,000 kPa).

Those capable of being charged to 3,000 psi (21,000 kPa) are tested to 4,400 psi (30,000 kPa).

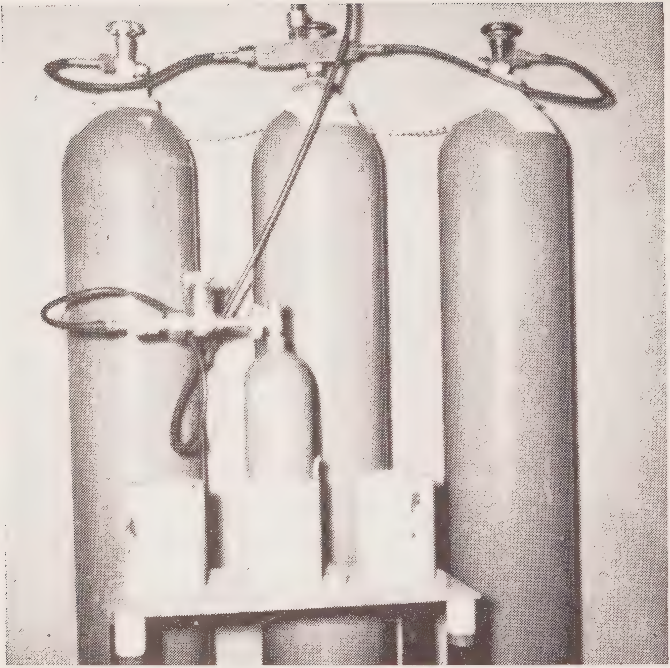


Fig. 70 — Charging Apparatus Bottles With Large Cylinders in Vertical Position.

Air or Oxygen Bottle Deterioration

When drawn from the large cylinder the air or oxygen contains some moisture, which is carried into the small bottle during refilling. The moisture hastens oxidation of the steel of the bottle, causing scale, sediment, rust, and pitting, and weakens the walls of the bottle.

These changes occur with no visible sign on the outside of the bottle. Visual examination of the inside often fails to disclose defects. Hydrostatic pressure is a means by which the condition of the bottle can be determined.

Questions on Chapter V

1 Describe the method of charging bottles by equalization.

2 What lubricant mixture is used on the oxygen pump?

3 Why is it dangerous to use oil or grease for lubricating the pump?

4 Describe the method of making the "Negative Leak Test" on the BG 174 with the Universal Tester.

5 When and when only may the 3,000 psi (21,000 kPa) setting be used on the Drager High Pressure Pump?

6 Why should oxygen cylinder valves be opened slowly?

7 What standard of purity is required for oxygen used in oxygen breathing apparatus?

8 How often, and at what pressure, are Drager BG 174 cylinders tested?

Chapter VI

General Rescue Team Emergency Practices

Maintenance of Rescue Teams on Rescue and Recovery Operations

All members of mine rescue teams should report ready to work fully equipped with suitable clothes.

All members of rescue teams sent underground should have had adequate training in such work.

In order that members of rescue teams may keep physically fit during mine rescue and recovery operations, the following arrangements should be made and adhered to:

1. No member should remain longer than 6 hours on one shift. During this period no man should be permitted to remain under oxygen longer than 2 hours, except in extreme emergency.
2. No one should be permitted to undertake a second shift until after he has had at least 6 hours rest.
3. No one should be permitted to work in irrespirable air without having been examined and found physically fit by a physician or, in the absence of a physician, by the most competent person present.
4. Bathing facilities, preferably shower baths with hot and cold water, should be available for the men coming off a rescue and recovery shift.

5. Plain, well prepared food, not too rich in sugar and fats, should be eaten in moderation. No food, including candy, should be eaten for one hour before taking active part in rescue and recovery work.

6. Comfortable, clean sleeping quarters should be provided, where necessary, for members of rescue teams.

Objects of Rescue and Recovery Work and Exploration During and After Mine Fires

Careful consideration should be given to the method and extent of the exploration plan and whether the results that may be obtained justify it. Can it be made with safety to the rescue teams, and will it increase the possibilities of saving the lives of trapped men.

The three main objects of mine rescue and recovery work are locating trapped men and bringing them to surface, locating and extinguishing incipient or active fires and, after the fire danger is over, examination of the mine for assurance that there are no dangerous concentrations of noxious gas which would prevent normal operations in any portion of the mine.

The director of rescue teams should consider the following items when making his plans:

1. probable conditions in the part of the mine to be explored as known from information already available;

2. route of travel;

3. visibility;

4. familiarity with location;

5. the number of rescue men available; and

6. the limitations of men and apparatus.

Decisions may have to be made by the director of rescue operations concerning the rescue or recovery of entrapped men.

Rescue teams may be able to fight mine fires at close range and direct streams of water to the best advantage. When a mine fire cannot be fought directly on account of its magnitude or dangerous conditions, they can put in seals or bulkheads. When a sealed area is opened, teams with suitable apparatus may explore it and find whether or not the fire is out before ventilation is restored.

Number of Men Required for Mine Rescue and Recovery Work

Oxygen breathing apparatus should be used only when there are enough trained men available to form a five man team to perform the assigned work.

Fifteen trained men is a satisfactory number to complete the team organizations at the fresh air base, this could be as follows:

1. Five men constitute a standard mine rescue team for work in irrespirable atmospheres.

2. Five men, in apparatus but not under oxygen, should remain at the fresh air base as a standby team.

3. Five men acting as a back up team in reserve may be used as assistants at the fresh air base until required as the standby team.

Although this organization is the ideal to be strived for, during the early stages of the emergency the deployment of the five-man teams is dictated by urgent conditions or endangered life.

Time Limits for Rescue Trips

All watches should be synchronized and any instructions regarding time limits strictly adhered to. For returning to the fresh air base a team should ordinarily allow twice the amount of time used on the ingoing trip.

If the amount of oxygen in the apparatus bottle worn by any member of a team has been reduced to twice the amount used on the ingoing trip, the whole team should return to the fresh air base immediately.

An exception to this procedure may be made in cases where extensive exploration or gas testing has been done on the way to the objective. Only the time or oxygen required for a direct return trip to the fresh air base need be considered.

If a rescue team is overdue in returning to the fresh air base, the standby team should be sent to assist, even at the cost of delaying operations.

Fresh Air Base

The fresh air base is the headquarters set up as a base of operations from which rescue and recovery work in irrespirable atmospheres may be conducted. A director of operations, with the required assistants, should be stationed at the base. If there are more than one of these bases it may be necessary to set up a general headquarters. The base may be on surface or underground, as conditions require, and should be as near the scene of operations as possible. The essentials of a fresh air base include the following:

1. an assured supply of fresh air;
2. an assured travelway for men and materials to surface in fresh air, if underground;
3. communication with headquarters on surface by telephone or messenger;

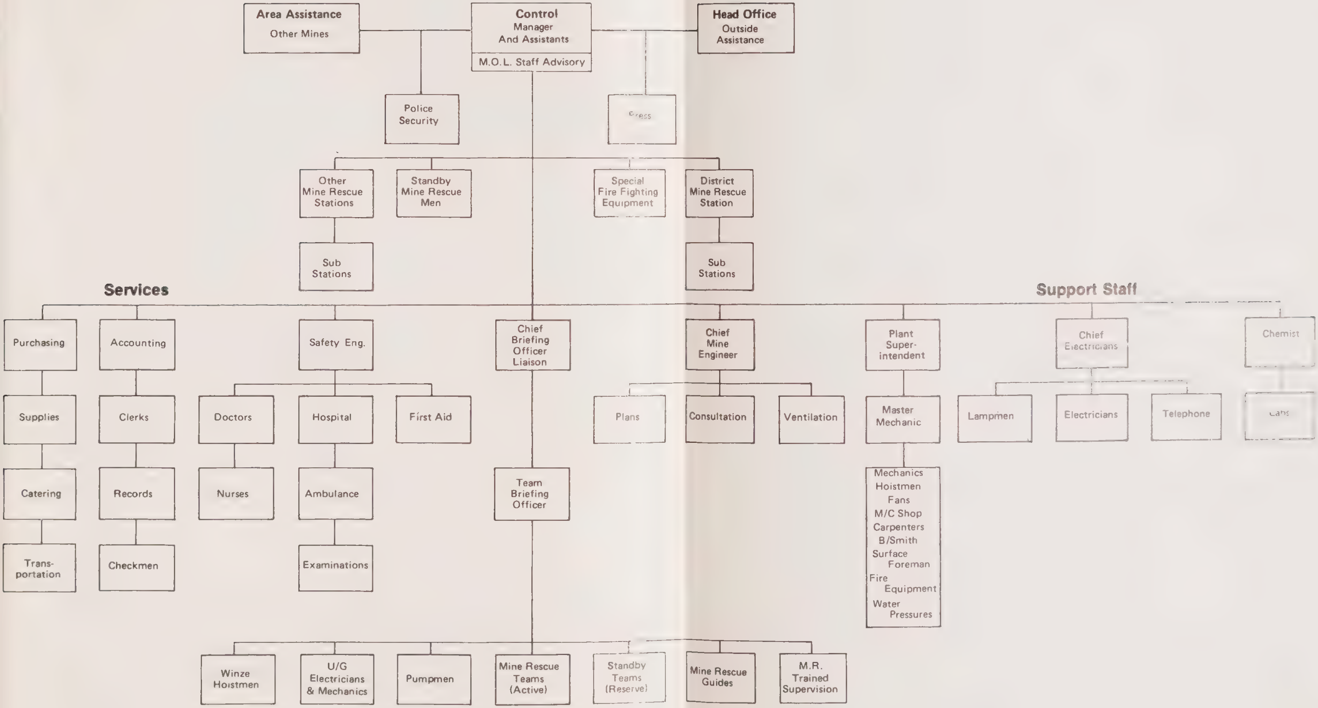


Fig. 71 — Fire Organization Chart and Control Group

Six Team Arrangement

Rotation of Mine Rescue Teams in Event of a Fire Underground
24 hour period

This arrangement is made up to a maximum force of six teams, and [illegible]ows for six hours on duty and six hours complete rest. As more teams become a[illegible] and if the emergency indicates an extensive operation, a nine team arrangement is advisable, whereby the team members would have a twelve hour rest period.

	Time											
Description												
1	Active				Reserve	Stand-by at F.A.B.	Active				Reserve	Stand-by at F.A.B.
2	Stand-by at F.A.B.	Active				Reserve	Stand-by at F.A.B.	Active				Reserve
3.	Reserve	Stand-by at F.A.B.	Active				Reserve	Stand-by at F.A.B.	Active			
4		Reserve	Stand-by at F.A.B.	Active				Reserve	Stand-by at F.A.B.	Active		
5.			Reserve	Stand-by	Active				Reserve	Stand-by	Active	
6.				Reserve	Stand-by at F.A.B.	Active				Reserve	Stand-by at F.A.B.	Active

Fig. 72 — Rotation of Mine Rescue Teams in Event of a Fire Underground (Six Team Arrangements) 24-hour Period

Nine Team Arrangement

Rotation of Mine Rescue Teams in Event of a Fire Underground
24 hour period

This arrangement is made up for a maximum of twelve teams and allows for six hours on duty and twelve hours complete rest

Date

Team No	Description	Time											
1.		Active							Reserve	Stand-by at F.A.B.	Active		
2.		Stand-by at F.A.B.	Active							Reserve	Stand-by at F.A.B.	Active	
3.		Reserve	Stand-by at F.A.B.	Active							Reserve	Stand-by at F.A.B.	Active
4			Reserve	Stand-by at F.A.B.	Active							Reserve	Stand-by at F.A.B.
5.				Reserve	Stand-by at F.A.B.	Active							
6.					Reserve	Stand-by at F.A.B.	Active						
7						Reserve	Stand-by at F.A.B.	Active					
8							Reserve	Stand-by at F.A.B.	Active				
9.								Reserve	Stand-by at F.A.B.	Active			

Signed

Fig. 73 — Rotation of Mine Rescue Teams in Event of a Fire Underground (Nine Team Arrangement) 24-hour period

4. the best illumination possible;
5. sufficient room to permit efficient work without confusion.

The fresh air base should be equipped with tables, benches for the reserve teams, benches for overhauling rescue apparatus, tools and repair parts for maintaining apparatus and the necessary tools and supplies for carrying on the work in hand.

There should be a sufficient staff to direct the work and maintain operations on the fresh air side of the base.

Briefing a Team

Briefing a team should be carried out only after all decisions in connection with the operations to be conducted have been made so that there will be no argument as to the proper steps to be taken once briefing commences. If possible, briefing should be done in a quiet room where questions may be answered and the work to be done by the team thoroughly explained, without confusion.

All pertinent instructions should be issued in writing to the team captain.

The time limits of the trip should be understood and watches synchronized.

Duties of the Captain of a Rescue Team

The team captain should take charge of and be responsible for the discipline, general safety and work performed by his team. ***He should take orders only from the mine official in charge of the operation.***

Preparatory to Going Underground

Preparatory to going underground the team captain should carry out the following procedure pertaining to the operation.

1. Ascertain that the members of the team are in fit condition to undertake the job.
2. Make sure that each member of the team inspects and completes the Field Tests on the apparatus he is about to wear. If Type N masks are being worn, new canisters should be used.
3. Check (or have members of the team check) the Flame Safety Lamp, CO detector, signal whistles, telephone lines and telephones, link lines and if required, a guide line. Be sure that each team is equipped with oxygen self-rescuers or other suitable apparatus.
4. Understand the instructions clearly and discuss them with the team so that each man will understand what he has to do.
5. Note the time the team has been allowed for the trip and synchronize watches with that of the official in charge.
6. See that the required tools and materials are on hand and equally distributed among the team so that each man will carry his share.
7. Make sure that he has level plans, notebook, pencil and chalk to take underground with him.
8. Have the team put on the apparatus and "get under oxygen" when ready to proceed; then inspect their equipment as follows:
   (a) Headstraps and buckles for twists.
   (b) Facemask, positioned correctly, tight seal.
   (c) Breathing tubes — not twisted.
   (d) Main bottle valve open (must try it).

(e) Observe gauge reading and record pressures.
(f) Check overall condition of man (sign or verbally).
(g) Vice-captain to make similar check of Captain's apparatus.
(h) Check signal whistles.
(i) Captain and Vice-captain carrying apparatus tools.
(j) Check time limits with briefing officer.
(k) Synchronize watches before leaving FAB.

After Going Underground

After going underground the team captain should carry out the following procedure:

1. Discourage excessive talking.

2. Note and write down any unusual conditions encountered during the trip. Make notes of all CO detector readings and safety lamp observations. Mark all obstructions and unusual conditions on the level plans. Bear in mind the fact that the team will have to overcome the same obstructions and unusual conditions on the return trip.

3. Mark the route of travel, in chalk or spray paint, by an arrow pointing to the fresh air base.

4. Shortly after entering or re-entering contaminated air at any time, halt the team and recheck the condition of the team members, the gauge readings and the apparatus.

5. Proceed carefully and stop to rest as often as conditions warrant. During halts observe gauges and function of the apparatus. If the rescue of men is involved speed may be necessary but should be governed by conditions and common sense.

6. Before passing through ventilation doors for the first time, check doors for damage, heat and position. If men may be taking refuge behind the doors, communicate with them before opening.

7. When passing through ventilating doors leave them as found, unless specific instructions have been given to leave the doors otherwise.

8. A lighted flame safety lamp and a carbon monoxide detector should be part of the standard equipment carried by every mine rescue team travelling underground either in practice or in actual operations. Before a team captain permits any team member to remove his breathing apparatus while underground, he must be certain the air is safe to breathe.

   To be sure the air is safe, tests for oxygen and carbon monoxide must be made by observing the lighted flame safety lamp and by using a carbon monoxide gas detector. No carbon monoxide should be present.

9. Remember the fact that it will be just as necessary to halt, rest and check apparatus when retreating as when advancing. Keep the team from becoming disorganized if anything should happen to a member or if an apparatus should fail to function properly. Use the bypass if necessary and the team return to the fresh air base as quickly as possible.

10. Whenever possible, maintain communications with surface or report frequently. Establish time limits for telephone calls to be made.

11. Carry out the orders given by the briefing official. Bring the team back to the fresh air base on time, even if the work assigned has not been completed. Make a report.

The success or failure of mine rescue and recovery operations depends a great deal on the ability of the team captains to lead their teams.

Rescue Team Organization

Rescue Team Guides

In a major fire it will generally be necessary to bring in rescue teams who are not familiar with the mine workings. To facilitate the necessary work in combatting the fire, team members familiar with the area should be assigned to each team.

Order of Travel

In mine rescue, as in any other team work, discipline is essential to efficiency. This discipline must be maintained both in training and in actual operations.

Whenever possible the team should travel in single file and approximately 1 metre apart. The team captain, or Number 1 man will always lead the team whether advancing or retreating, followed by members 2, 3, 4 and 5 in that order. Number 5 man assumes the responsibilities of vice-captain. If a trained supervisor accompanies a team, he should take the position as Number 2 man, where he would be in easy communicating distance to the captain.

The rate of travel cannot be laid down by any hard and fast rules. Conditions which will govern the rate of travel are

1. visibility;
2. obstructions to travel;
3. mental and physical condition of the team members;
4. amount of oxygen in the bottles; and
5. anything that may be applicable to local conditions.

Travelling on ladders "under oxygen" should be undertaken only after the value of this work in relation to the hazards involved has been carefully considered.

Fastening Team Members Together

When travelling in strange territory or in atmospheres where visibility is limited or may become so, the members of the rescue team are fastened together by means of a link line. In emergencies, where the link line is liable to become an additional hazard, e.g. when carrying a stretcher or patient, and as long as there is some means of keeping team members together, the link lines may be disconnected.

Definition and Description of "Lines" Used

The following terms have been standardized for mine rescue work.

Guide Line consists of a line or telephone cable stretched from the fresh air base or shaft station to the working face in such a manner that a team may guide itself through strange territory or dense atmospheres.

Link Line is a 4 ft. (1.5 m) length of 3/8 in. (10 mm) propylene rope with a heavy snap spliced to each end. D-rings to which these snaps are to be fastened are built into the special lamp belts used by Ontario mine rescue team members while wearing Drager BG 174 or any other type of breathing apparatus.

Passing a Team Through Ventilation or Fire Doors

A team captain should make certain that all doors are left as found unless he receives definite instructions, preferably in writing, to the contrary.

To ensure that this is done the following procedure is adopted:

1. The captain should halt the team. Disconnect link line.
2. Examine the door for damage, heat and position.
3. The captain should open the door and remain at it, holding the door open.
4. Still standing at the door, the captain should advance the team through the door until the last man is through.
5. When the last man is through the captain should halt the team.
6. The captain should then close the door, take his place at the head of the team, fasten link line and give the signal to advance.

Travelling in Smoke

When travelling in smoky atmospheres the mine rescue team members will find it advantageous to carry their electric cap lamps in their hands and use a probe stick to feel for obstructions and hazards.

If the smoke is very dense it is better to have the lamp as near the track as possible, letting the lamp hang by its cord so that the light is directed to the feet.

There is a disadvantage in carrying the light on the hat, as the reflection cast back by the solid particles of smoke close to the man's face tends to blind him.

Methods of Communication

Communication Between Fresh Air Base and Team

It is essential that means of communication be established between teams working ahead of a fresh air base and the base itself. When wearing breathing apparatus communication may be carried on by telephone, either electric or battery-powered. This is the ideal method of communication as the men in charge

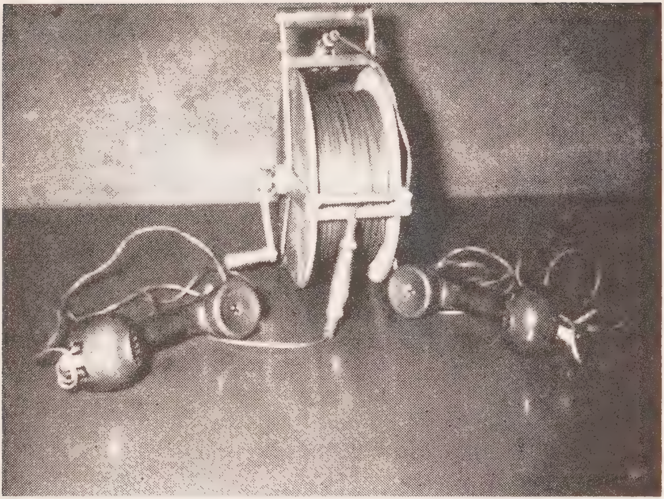


Fig. 74 — Battery-Powered Telephones and Reel

of operations are in constant touch with the advance teams. The assembly and parts of such a system are shown in *Fig. 74*.

Communication Between Team Members

Although team members may talk with one another, it is essential that conversation be limited. Whistle signals should be used for all team movements as follows:

Code of Signals

1 — Stop. **2** — Advance. **3** — Turn around. **4** — Attention or Emergency.

Signals given by mechanical means, such as whistles or horns, by the team captain to the team are repeated by the vice-captain.

Travelling With the Telephone

In order to minimize confusion and inconvenience when travelling with the mine rescue telephone, these procedures should be followed:

1. Number 2 man should carry the reel currently being used, and preferably in his left hand, to avoid striking his leg with the crank as it unwinds.
2. If extra reels are necessary they may be carried by team member 3, 4, or 5.
3. As the team captain inspects the team, the Number 2 man should follow him with the reel.
4. Standard procedure will be followed at ventilation doors, and the captain should hold the reel as the remainder of the team is moving through the door. Be very careful to see that the door in closing does not pinch the wire.
5. As the captain takes his place again at the head of the team, he will hand the reel back to the Number 2 man.
6. In retreating under normal conditions, the telephone wire should be rewound by Number 2 man, but if more than one reel has been used, he may exchange places with another man for the rewinding of subsequent reels.
7. In emergencies under actual conditions, e.g. where it becomes necessary to evaluate either a team member or a victim with all possible speed, the telephone reel should be disconnected and abandoned.

Marking Route of Travel

It is necessary that the route of travel be marked in such a manner that it may assist the team to find its way back to the fresh air

base and to show a team that is following the route that has been taken.

A broad arrow chalked on the side of the travelway, pointing toward the fresh air base or level station, is a recognized standard way of marking a route. When more than one rescue team is operating at a time, the team number should be written above the arrow.

Routes of travel should be clearly marked at all intersections, but are not necessary in travelways with no branches.

At the end of the travel the team captain should mark the wall with heavy vertical lines and place, near this mark, the time, the date, team number, and his initials.

When retreating, the team captain should cancel the markings he made on the ingoing trip with an "X", thereby indicating that the team has travelled that route, but has retreated.

When visibility is at zero, dependence must be placed on the sense of touch. If the team is to travel in drifts or crosscuts where track is laid, it is simple to follow the track by sliding one foot along a rail. When a switch is reached it should always be left so that it makes a continuous track to the fresh air base which can be followed by a retreating team. If no track exists, much time can be saved by having several teams in apparatus install a guideline to the working face, each team advancing it in turn. As each team completes the installation of its allotted section of guide line, the captain should mark the place where the line ends with an obstacle across the drift. This may be a small pile of rocks, boards, timber, or anything available which can be identified by touch. On reaching the fresh air base the team captain should describe such obstruction clearly in his report.

The habit of marking the route of travel with chalk at all times should be formed when the team is in training. It should be done even when using guide and telephone lines, as loose rock may fall and cut such lines.

Use of Vehicles For Transportation

The conditions which the teams encounter will dictate the procedures they will have to take. The regulations for the use of motor vehicles in mines is the basis for the use of vehicles by the mine rescue team.

1. The team captain and the briefing officer shall note the normal walking distances on the mine plans. This will give some indication how far the team would travel on foot should the vehicle need to be abandoned.

2. Teams should travel in fresh air and in good visibility whenever possible. Extreme caution must be used when light smoke is encountered in the travelway. In dense smoke motor vehicles should not be used unless the travelway has been examined on foot for hazards or impaired personnel, and then only for short distances. Each stage of advance should not exceed 80 m (250 ft).

3. The vehicle must be equipped with good lighting and the necessary emergency equipment and tools.

4. When travelling in light smoke the horn should be sounded frequently.

5. During travel the team captain must report on the progress from all pre-arranged contact points.

6. Should the vehicle be abandoned it should be parked at the side of the roadway and the engine must be turned off. Warning reflectors or signals should be oriented to warn other teams. Maintain a clear roadway for other vehicles.

7. The mine rescue team member driving the vehicle must be a competent vehicle operator.

8. The operator of a motor vehicle would be more versatile if equipped with a demand apparatus complete with extension hose and jumbo cylinder instead of BG 174 apparatus.

9. Control doors may need to be opened manually, in which case these would have to be held open while the vehicle passes through. The captain will be responsible for the correct positioning of the doors.

Use Of Burning and Welding Equipment

The hazardous practice of burning and welding operations while "under oxygen" must be emphasized.

The danger is the possibility of hot slag burning into the oxygen enriched breathing apparatus through the rubber components of the apparatus and then erupting into flame.

The recommended emergency procedure is:

1. A competent person is selected for the operation and must be trained in mine rescue and be properly equipped for burning and welding.

2. He will be the sixth person on the mine rescue team.

3. This man must be equipped with self-contained air breathing apparatus, preferably demand apparatus for connecting to a supplementary air supply with an extension hose.

4. He will work under the supervision of the team captain at all times.

5. When the assignment is completed the man should be returned to fresh air immediately.

Duration of Rescue Operations in High Temperatures

Experience has proved that the endurance of mine rescue team members in hot and humid atmospheres is limited and a two-hour team rotation may prove impossible, in which case, additional teams will be required to compensate for the shorter work period. After being exposed to extreme temperatures and humidity for even a very short period the team should rest for at least two hours.

In temperatures of approximately 110°F (45°C) dry bulb reading and 100°F (38°C) wet bulb reading, the period under oxygen may be reduced to twenty minutes or less.

The following chart, developed at the Mine Rescue Centre, Essen, W. Germany, may be used as a guideline for exposure limits.

Time Limits While Under Oxygen in Extreme Conditions

Wet Bulb Temperature Centigrade	Difference Between t_f and t_t		
	Below 5°C	5 to 10°C	Above 10°C
(t_f)	Duration of Action in Minutes		
29	90	85	80
30	80	75	70
31	70	65	60
32	60	55	50
33	50	45	40
34	45	40	35
35	40	35	30
36	35	30	25
37	30	25	20
38 - 40	25	20	15

(t_f) — Wet bulb temperature

(t_t) — Dry bulb temperature

Barricades

General Considerations

When miners have been trapped by fire in the mine they should not rush aimlessly around, but should immediately take action to protect themselves.

When the way of escape is cut off but the local atmosphere is free of contaminating gases, consideration should be given to the building of a barricade or bulkhead. Tools, timber, canvas, water, dinner buckets, and anything else that might be useful should be collected.

A suitable place should be chosen for the erection of the barricade and its construction started without delay, as the deadly gases often travel quickly. The time required to build an efficient barricade will vary from 30 minutes to 2 hours, depending on conditions.

To provide a maximum quantity of air, as much area as possible in drifts and crosscuts should be included in the barricaded area, regardless of the number of men in the party.

Before constructing barricades it is necessary to make sure that there are no other openings or connections with other workings through which gases can enter, also that the crosscut or drift is not in broken ground through which gas can seep.

After the barricade has been built the men should keep as still as possible, because a man uses several times as much oxygen when he exerts himself as when he keeps at rest. However, somebody should walk around occasionally to mix the air. All the men should not congregate in one place.

All open flame lamps should be extinguished to conserve oxygen. Electric batteries should not be used needlessly. Smoking should be prohibited.

Food and water should be conserved.

A sign should be placed outside any barricade stating that there are men behind it and giving the number. Badge numbers

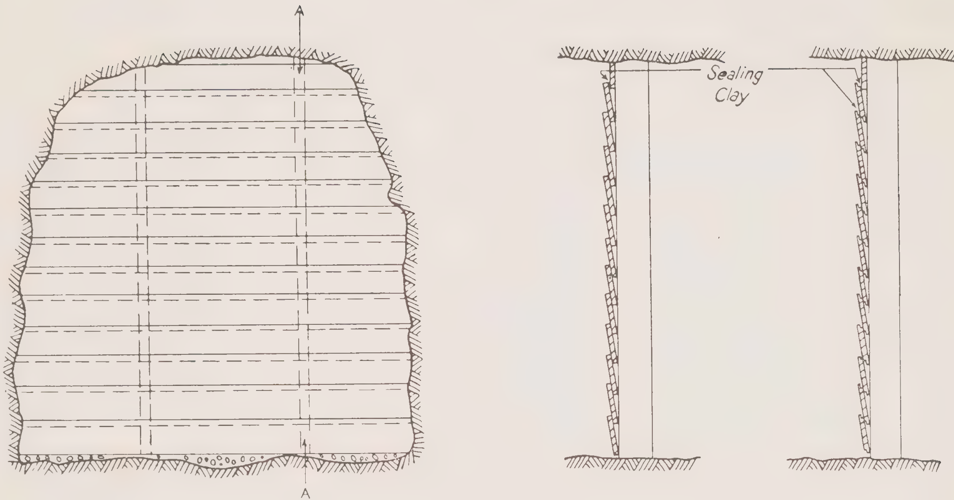


Fig. 75 — Temporary Barricades of Lumber

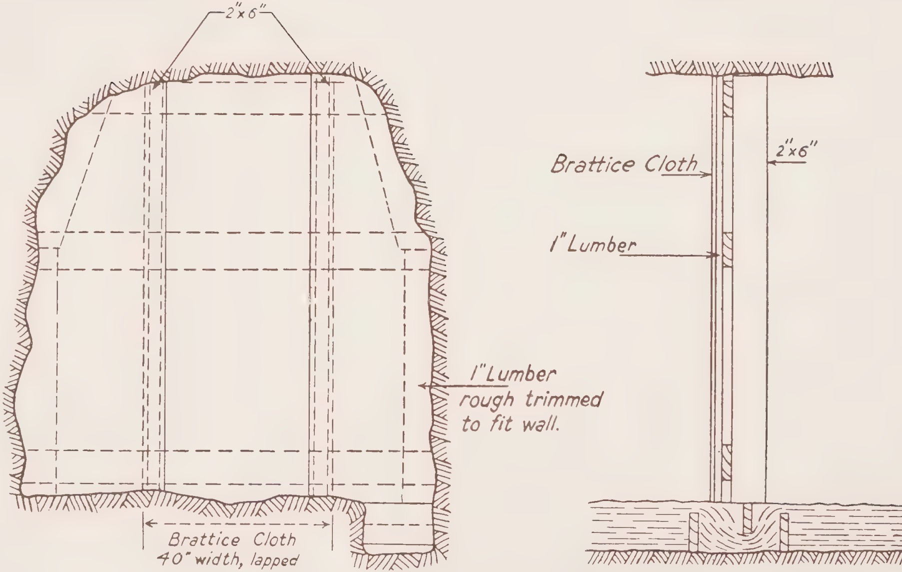


Fig. 76 — Temporary Barricades of Brattice Cloth

Note: the overlapping of the edges and the method of damming the ditch.

Fig. 77 — Brattice Cloth Barricade

would also be advisable.

If possible, barricades or bulkheads should be erected in such a location that a valve in the compressed air line will be inside the barricade. The valve should be opened occasionally to furnish additional air.

If circumstances permit and materials are readily available, a second barricade should be erected to a distance of 10 to 20 m inside the first to provide an air lock.

Fig. 78 — Sandbag Barricade, Completed

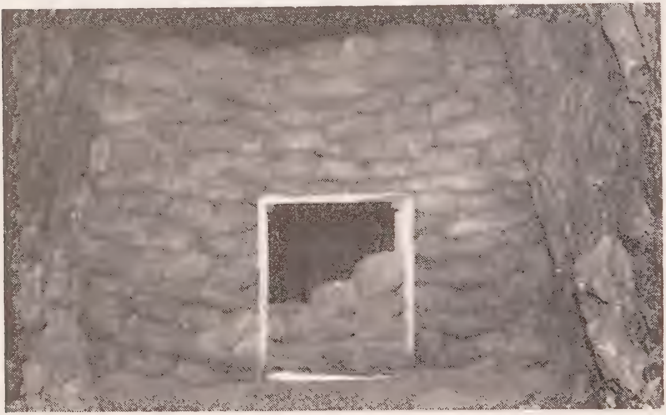


Fig. 79 — Sandbag Barricade (Showing Travelway)

Methods of Construction

Barricades vary in construction, depending on the time and materials available and the requirements of the structure.

Barricades constructed by men whose escape has been cut off by noxious gases may be built of any material such as rock, lumber, canvas, or ventilation tubing which can be found in the area.

If large pieces of rock are used for the barricade, two walls about 3 ft. (1 m) apart should be built and the space between should be filled with fine materials, preferably mud. The stoppings must be as air tight as possible. It is more difficult to make board stoppings air tight than those of dirt, rock, soft clay, or mud. All chinks and holes in the barricade should be stopped with clay, rags, clothes, or similar material. If a piece of pipe is available it could be placed through the stopping or barricade and plugged at the inner end for use as a vent, or communication with mine rescue teams.

Barricades built by mine rescue teams for the control of ventilation may be either temporary structures or permanent stoppings to seal a fire area.

Temporary barricades may be built of material such as sandbags, brattice cloth, lumber, or sheets of building board. At least two should be built at each site, usually 15 to 30 ft. (5 to 10 m) apart, to form an airlock. They usually require from 30 minutes to an hour each to build including the erection and the claying of all joints.

The most common type is built of lumber or shiplap *(Fig. 75)*. A sufficient number of posts are stood in an upright position. Starting at the top, the first board is nailed across the posts, fitted approximately to the contour of the roof, and the second board is laid with an overlap of about 2 in. (5 cm). This overlapping is continued until the drift is closed. Clay is packed around the sides and in each trough formed by the overlapping of the boards. Care should be taken that all joints are well sealed.

Fig. 80 — Lumber Barricade (Showing Door Removed)

A lumber barricade may be erected with prefabricated doors and door frames of proper size to suit the mine travelway. Such a barricade enables the rescue team to pass in or out of the fire area easily and quickly. This type of barricade is particularly suitable in advancing a fresh air base. The door frame is held in place and the openings around it are boarded up and sealed with clay. The door should be fitted with a suitable latch so it can be opened from either side.

A sandbag barricade has several advantages when used as a temporary stopping. It can be erected when the smoke is fairly dense, the bags can be filled on surface, it can be quickly erected and be made much stronger and more air tight than either brattice cloth or lumber barricades.

If there is a possibility that water might build up behind a barricade, a suitable water trap should be constructed. Such a

trap may be made by connecting two 90 degree, 4 in. (10 cm) pipe elbows to a 12 in. (30 cm) length of pipe to form a "U". This should be installed in the ditch or low spot under the barricade, and filled with water. This will prevent air movement through the pipe, but will allow any future accumulation of water to pass. *(See Fig. 76).*

Fig. 78 shows a completed sandbag barricade. *Fig. 79* shows a partially completed barricade with a frame for a travelway, but variations may be used, depending on available supplies and time.

Permanent barricades, seals or stoppings are constructed to seal a fire area permanently. They may be built of brick, concrete, stone, or tile. Pressure resisting, permanent barricades should conform to the rules of the Ontario Regulations 694/80.

Refuge Stations and Barricaded Areas

Refuge stations are becoming more numerous in Ontario mines, and, in many cases, they are used for dual purposes as lunchrooms and refuge stations. This keeps the workers familiar with the location.

Where the procedure in case of a fire in an underground mine provides for the use of a refuge station for workers, the refuge station shall:

(a) be constructed with materials having at least a one-hour fire resistance rating;
(b) be of sufficient size to accommodate the workers to be assembled therein;
(c) be capable of being sealed to prevent the entry of gases;
(d) have a means of voice communication with the surface; and
(e) be equipped with a means for the supply of,
    (i) compressed air, and
    (ii) potable water.

Ontario Reg 694/80

It should contain a door, opening outwards, capable of being sealed with clay or plastic material. Some means must be provided in the door to allow the escape of air pressure in the event the compressed air valve within the sealed area must be opened. A means of sealing this opening must be provided on the inside of the door.

Refuge Stations are advisable in the vicinity of winze collars, where they may be readily converted to Advanced Fresh Air Bases in the event of a fire in a location served by the winze.

The cubic content of a refuge station, without additional supply of fresh air from compressed air lines, determines the number of men that can occupy it, and the length of time they can safely remain. In breathing, the men consume oxygen from the air and give off an almost equal amount of carbon dioxide. When the proportion of carbon dioxide in the air of the enclosed space reaches 8 per cent, the men breathe heavily and are at the point of complete exhaustion. Men have lived for considerable periods in an atmosphere in which a carbide light would not burn, thus indicating that the air contained less than 13 per cent of oxygen. A man at rest consumes less oxygen and gives off less carbon dioxide than when working. In a confined space, however, the air will finally become unfit to sustain life. Experiments have shown that a man in a confined space requires approximately one cubic yard of air per hour (one cubic metre of air per hour). At the end of an hour this cubic yard of air will contain about 14 per cent of oxygen and 5 per cent of carbon dioxide. A flame lamp or match will not burn. On the basis of one cubic yard of air per hour (one cubic metre of air per hour), an enclosed space 10 ft. x 10 ft. x 10 ft. or 1,000 ft.^{3} (3m x 3m x 3m or 27 cubic metres) will support one man for approximately 30 hours before he begins to suffer through lack of breathing air. This minimum allowance of one cubic metre per hour per man, however, does not provide for loss of oxygen through absorption by the ore or timber in the enclosed space or for the contamination of the air by noxious gases.

In one metal mine the air in a barricaded drift 250 feet long, 6 feet high, and 6 feet wide (9,000 cu. ft., 255 m^3) kept 29 men alive for 36 hours. In the same mine another drift 130 feet long, 7 feet high, and 7 feet wide (6,500 cubic feet, 184 m^3) contained sufficient air to support 6 out of 8 men for 50 hours; the other 2 men were found dead. The 6 who were alive were all unconscious, but were revived.

The value of barricades cannot be too strongly emphasized. They have been the means of saving hundreds of lives in coal and metal mines. Many additional lives may be saved if men are properly instructed in their use.

Opening a Barricade

Before opening a barricade behind which men have taken refuge, the air outside should be made respirable if possible.

However, if delay in clearing the atmosphere outside the barricade should endanger the lives of the trapped men, an air lock should be constructed as close to the mens' barricade as possible, and the men removed with suitable apparatus.

A barricade which has been erected to seal off a fire should not be unsealed unless the director of operations has given definite orders to do so.

Questions on Chapter VI

1 What are the three main objects of rescue and recovery operations?

2 What is the preferred number of men required for rescue and recovery teams?

3 What are the time limits for rescue team trips?

4 Describe a fresh air base, its location, etc.

5 Describe the main essentials of a fresh air base.

6 What are the duties of the captain and members of a rescue team?

7 What are the responsibilities of a mine rescue team guide?

8 Describe the order of travel of a rescue team.

9 How are team members fastened together?

10 Describe the method of passing a team through closed fire doors.

11 When and why are lights carried in the hand by team members?

12 Define "link line", and "guide line".

13 What method of communication is used between a team and the fresh air base?

14 Give the standard code of signals as used by mine rescue teams.

15 Describe the method of marking the route of travel.

16 Describe the general requirements in locating barricades for refuge purposes.

17 Describe recommended procedures for men behind barricades.

18 Describe methods of construction of the following:
(a) life saving barricades
(b) barricades erected by mine rescue teams
(c) permanent barricades

19 What is the life sustaining capacity of a barricaded area 3m x 3m x 3m?

20 What precautions should be taken before opening a barricade behind which men have taken refuge?

21 On what authority should a barricade erected to seal a mine fire be opened?

22 What procedure should be followed by a mine rescue team immediately after entering contaminated air?

23 What precaution must be taken before removing breathing apparatus while underground?

24 Where, when, and how should the briefing of a mine rescue team be carried out?

Underground Fires

Causes of Metal Mine Fires

Most fires occurring underground can be placed in the following categories:

1 **Electrical:** Battery locomotives, power cables, trolley wires, motors, electric heaters and even electric light bulbs.

2 **Diesel Powered Equipment:** Mobile, locomotive or portable equipment.

3 **Burning and Welding:** Use of compressed gases, electrical welding.

4 **Smoking or Open Flame:** Whether deliberate or accidental.

5 **Friction:** Conveyor belts, drive units, brakes and clutches, gear boxes.

6 **Spontaneous combustion:** Sulphide ores, tailings backfill, accumulation of combustible materials.

The categories of fires are listed in order of their record of occurrences in recent years. Fires involving electrical quipment accounted for almost 50 per cent of the occurrences. Also high on the list are fires involving diesel equipment and burning and welding which account for another 30 per cent.

Definition of Fire and Explosion

Fire: A rapid oxidation of material in which heat is produced to a sufficient degree to ignite gases or vapours released by such heating.

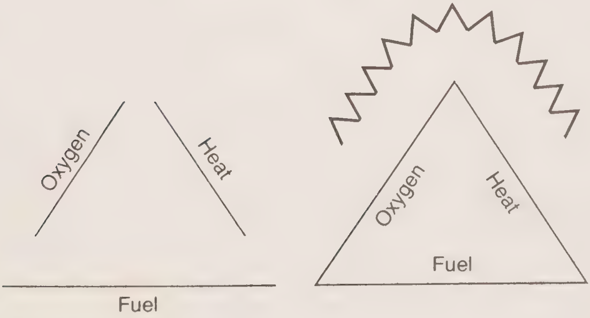
Explosion: If the fire reaction is such that an appreciable rise in pressure occurs it is called an explosion.

Fire Triangle

In summary, the science of fire protection rests upon the following principles:

1. An oxidizing agent, a combustible material, and an ignition source are essential for combustion.
2. The combustible material must be heated to its ignition temperature before it will burn.
3. Combustion will continue until:

   (a) The combustible material is consumed or removed,
   (b) The oxidizing agent concentration is lowered to below the concentration necessary to support combustion,
   (c) The combustible material is cooled to below its ignition temperature,
   (d) Flames are chemically inhibited.



Extinguishers in Relation to Classes of Fires

It is well known that most large fires start as small ones, and can usually be extinguished easily if discovered in the early stages and if suitable equipment or material is readily available. This applies to fires both on surface and underground.

To facilitate proper use of extinguishers on different types of fires, the NFPA Extinguisher Standard has classified fires into the following four types:

Class A: Fires involving ordinary combustible materials (such as wood, cloth, paper, rubber, and many plastics) requiring the heat absorbing (cooling) effects of water, water solutions, or the coating effects of certain dry chemicals which retard combustion.

Class B: Fires involving flammable or combustible liquids, flammable gases, greases, and similar materials where extinguishment is most readily secured by excluding air (oxygen), inhibiting the release of combustible vapours, or interrupting the combustion chain reaction.

Class C: Fires involving live electrical equipment where safety to the operator requires the use of electrically nonconductive extinguishing agents. (Note: When electric power is disconnected, Class A or B extinguishers may be used).

Class D: Fires involving certain combustible metals (such as magnesium, titanium, zirconium, sodium, potassium, etc.) requiring a heat absorbing extinguishing medium not reactive with the burning metals.

Some portable fire extinguishers are of primary value on only one class of fire; some are suitable on two or three classes; none is suitable for all four classes of fire.

Portable Fire Extinguishers

Fire extinguishers of types suitable for the hazard that might be expected, when properly maintained will provide protection.

Water Extinguishers: This type utilizes the simplest fire fighting medium available. The water may be pumped or stored under pressure in suitable containers. Larger sizes of containers include the 660-litre Fog-O-Car, mounted on wheels and pressurized by compressed air, nitrogen or carbon dioxide. ***Water type extinguishers are effective and safe on Class A fires only. They must not be used on Class C fires.***

Carbon Dioxide Extinguishers are safe to use on Class A, B and C fires, but are only moderately effective on Class A. They are available in different sizes, and in larger mobile models. The extinguishing agent is liquid carbon dioxide while in the extinguisher, but is discharged as frozen vapour which converts quickly to carbon dioxide gas, and extinguishes fires by excluding or diluting oxygen.

Dry Chemical Extinguishers are safe to use on Class A, B, and C and are highly recommended for Class B and C fires.

The extinguishing agent is basically sodium bicarbonate or potassium bicarbonate in dry powdery form, to which has been added a component to repel moisture and maintain free flow. The powder is expelled under pressure, produced either by compressed air stored in the extinguisher, or by puncturing a small carbon dioxide cartridge attached to or confined within the extinguisher. As the ejected powder granules become warmed by the heat of the fire, each tiny particle produces carbon dioxide gas, which acts by excluding or reducing oxygen within or surrounding the fire.

Water Fog and Foaming Agents

Water Fog is a fire fighting device useful and safe on Class A and B fires. Water fog is composed of fine particles of water expelled through a special high pressure nozzle. As the super fine spray hits the fire, the heat is reduced and the water is turned to steam, cutting off the oxygen and extinguishing the fire.

Water fog, produced by special fog nozzles is useful as a heat barrier for rescue teams advancing towards the fire. Water damage is also greatly reduced, compared with the use of straight stream nozzles.

High Expansion Foaming Agents

''High expansion'' foam is a biodegradable agent for control and extinguishment of Class A and Class B fires and is particularly suited for flooding in confined spaces. The foam is a mass of bubbles mechanically generated by the passage of air or other gases through a net, screen, or other porous medium that is wetted by an aqueous solution of surface active foaming agents. Under proper conditions, foams with expansions of 100:1 to 1000:1 can be generated.

High expansion foam is a unique vehicle for transporting wet foam masses to inaccessible places, for total flooding of confined spaces, and for volumetric displacement of vapour, heat, and smoke. Tests have shown that under certain circumstances high expansion foam when used in conjunction with water from automatic sprinklers will provide more positive control and extinguishment than either extinguishing agent by itself. Optimum efficiency in any one type of hazard is dependent on the rate of application and the foam expansion and stability. High expansion foam has several effects on fires:

1. When generated in sufficient volume it can prevent air, necessary for continued combustion, from reaching the fire.

Four Classes of Fire

KNOW YOUR FIRE EXTINGUISHERS	WATER TYPE		CARBON DIOXIDE	DRY CHEMICAL	MULTI-PURPOSE
	 STORED PRESSURE	 WATER PUMP TANK	 CO_2	 DRY CHEMICAL	 DRY CHEMICAL
CLASS A FIRES WOOD PAPER TRASH HAVING GLOWING EMBERS (A)	YES	YES	NO (BUT WILL CONTROL SMALL SURFACE FIRES)	NO (BUT WILL CONTROL SMALL SURFACE FIRES)	YES
CLASS B FIRES FLAMMABLE LIQUIDS GASOLINE OIL PAINTS GREASE ETC (B)	NO	NO	YES	YES	YES
CLASS C FIRES ELECTRICAL EQUIPMENT (C)	NO	NO	YES	YES	YES
USUAL OPERATION	UPRIGHT SQUEEZE HANDLE OR TURN VALVE	UPRIGHT AND PUMP HANDLE	SQUEEZE RELEASE	RUPTURE CARTRIDGE SQUEEZE NOZZLE TO RELEASE	RUPTURE CARTRIDGE SQUEEZE NOZZLE TO RELEASE
RANGE	10 12m	10 12m	1 - 3m	2 - 7 m	5 10m
SERVICING	CHECK AND PRESSURE	CHECK PUMP AND FILL WITH WATER ANNUALLY	WEIGH SEMI ANNUALLY	WEIGH GAS CARTRIDGE AND CHECK CONDITION OF DRY POWDER	WEIGH GAS CARTRIDGE AND CHECK CONDITION OF DRY POWDER
CLASS D FIRES (D) YELLOW STAR	THIS SPECIALIZED CLASSIFICATION INCLUDES FIRES IN COMBUSTIBLE METALS SUCH AS MAGNESIUM ALUMINUM SODIUM POTASSIUM AND OTHERS A SPECIAL EXTINGUISHING POWDER USUALLY WITH A SODIUM CHLORIDE BASE IS USED TO COMPLETELY COVER THE FIRE THUS HAVING A SMOTHERING EFFECT				

Fig. 81 — "Know Your Fire Extinguishers"

2. When forced into the heat of a fire the water in the foam is converted to steam, reducing the oxygen concentration by dilution of the air.

3. The conversion of the water to steam absorbs heat from the burning fuel. Any hot object exposed to the foam will continue the process of breaking down the foam, converting the water to steam, and of being cooled.

4. Because of its relatively low surface tension the solution from the foam, which is not converted to steam, will tend to penetrate Class A materials. However, deep seated fires may require further control.

5. When accumulated in depth, high expansion foam can provide an insulating barrier for protection of exposed materials or structures not involved in a fire, thereby preventing the spread of fire.

When foam is generated from the gases of combustion it becomes toxic, and entry to a foam filled passage must not be attempted without self-contained breathing apparatus. The foam mass also obscures vision, and life lines must be used if entering into it.

High Expansion Foam Generator

Ontario mine rescue stations are equipped with diesel powered, high expansion foam generators capable of producing 6,000 cu. ft. (170 m^3) of high expansion foam per minute with a ratio of 1,000 parts of air to one of water.

The unit uses 45 gallons (200 litres) of water and 3 litres (0.7 gallons) of foam concentrate per minute.

The foam generator consists of a fan, a one-cylinder diesel engine, a plenum chamber, a bank of four spray nozzles and a knitted nylon net on which the foam is formed. Water is fed into the unit through a 1.5 inch (3.8 cm) hose, and an "in-line"

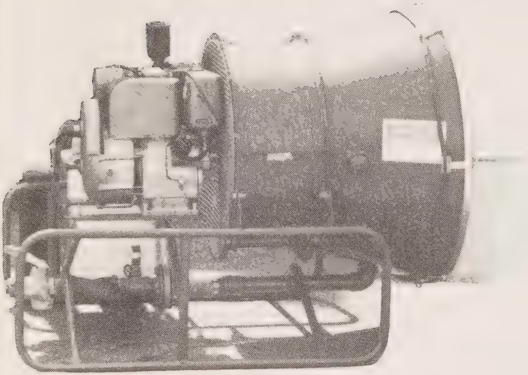


Fig. 82 — High Expansion Foam Generator

proportioner draws foam concentrate through a metering orifice into the water stream.

A mixture of foam concentrate and water is sprayed at about 12 psi (80 kPa) onto the nylon net through the nozzles, creating a constant spray pattern for equal wetting of the net. The foam created by air passing through the netting is delivered through tubing.

Operation of the Foam Generator

The water hose is connected to a hydrant or pipe valve in a line capable of supplying 45 gallons (200 litres) of water per minute, at a minimum pressure of 50 psi (350 kPa). The water supply should be reasonably free from dirt or scale which might clog the inlet strainer.

The water pressure gauge reading should be held constant

even though the supply pressure varies. Should the pressure reading fall below the mark on the gauge dial, the pressure is too low, or the inlet strainer is plugged with dirt.

The stainless steel pickup tube is fitted with a fine screen to prevent the entrance of foreign material into the metering orifice.

Procedure for Using the Foam Generator Underground

1. Set up the generator adjacent to a previously prepared barricade with an opening at least 2 m^2 or to a doorway in a drift or roadway.
2. Attach one end of the desired discharge tubing to the connection on the generator. Carry the other end through the doorway and fasten or brace it to the door frame.
3. Open the valve on the water supply line and flush the line until the water runs clear. Rusty water makes poor foam.
4. Connect the 1.5 in. (3.8 cm) water hose to the unit and pressurize the line up to the inlet water control valve.
5. Start the engine. The engine may require further adjustment as the concentrate is applied on the netting.
6. Open the inlet water control valve until the pressure reaches the prescribed reading of 12 psi.
7. Insert the detergent pickup tube into the foam concentrate container.

After use, the discharge tube should be cleared of residual foam. A convenient way to clear the tube is to have two men, one on either side, pass a rope under the tube, raise it slightly and walk its entire length from the generator to the open end while running the fan at high speed.

The tube should be hung up to dry thoroughly after use and rolled so that the guide rings are on the inner end of the roll and

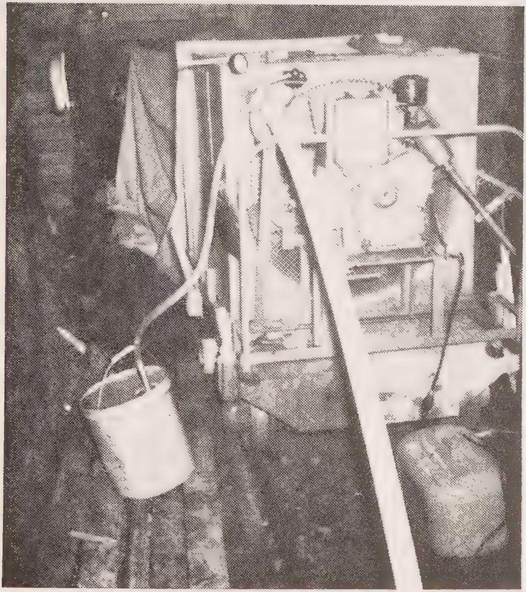


Fig. 83 — High Expansion Foam Generator Set Up Underground

the machine end on the top. This will allow the tube to be connected and rolled out correctly by fan pressure the next time the unit is used.

The proportioner and pickup tube should be flushed with clear water after use. Check the screen on the pickup tube for cleanliness, run water through the nozzles to be sure they are not clogged, and check the screen at the hose inlet. ***Foam detergent is corrosive with metal.***

It is important that mine rescue team members become proficient with the use of the high expansion foam machine. A trained operator can vary the quality and quantity of foam being generated.

Fire Attack with High Expansion Foam

The tremendous volume of foam being discharged into an area seals it and prevents fresh air from reaching the base of the fire. Once the fire has been reached, the foam continues to exclude fresh air and holds the steam and oxygen deficient atmosphere around the fire.

When the water film of the bubble wall approaches a fire, radiant heat vaporizes the water in the foam front. The one part water in 1,000 parts air expands 1,700 times in forming steam. The resulting steam air mixture has an oxygen content of around 7.5 per cent, well below the level required to support combustion. Large volumes of steam thus formed displace additional hot gases and tend to create inert areas above the fire and limit its spread.

Bubbles cannot exist in contact with a dry surface. As a result high expansion foam wets down those areas where the water is needed. The surface tension of the water in the foam is quite low and penetration is thus deeper than with equal volumes of plain water.

Cooling and extinguishing are accomplished by a high steam atmosphere. The generator should be operated to produce foam at as high a rate as possible.

After the burning material has been covered, the foam covering should be maintained to cool the hot material.

Travelling Through High Expansion Foam

Persons wearing self-contained oxygen or air breathing apparatus may travel safely through the foam, even though submerged in it. Care should be taken that all team members are fastened closely together, and travel should be where it is known there are no hazards.

Do not enter foam wearing a canister type gas mask, as the filters will become saturated and completely close off the passage of air.

Questions on Chapter VII

1 Name and describe the four categories of metal mine fires.

2 Define Class A, B, C, and D fires.

3 Name types of portable fire extinguishers.

4 What is "high expansion foam"?

5 Describe the seven steps necessary for using the foam generator underground.

6 Under what conditions is travelling through high expansion foam to be permitted?

Ontario Mine Rescue Emergency Organization

Although the emergency organization is referring to the use of breathing apparatus equipped mine rescue teams, the same organization is beneficial during any mining emergency. The Ontario Mine Rescue Emergency Organization is included as a guideline for emergency preparedness.

Definitions

Mine Rescue: This is a practical procedure in mining, in which men are trained to wear breathing apparatus and use special equipment to save lives, and to recover property in case of an underground mine fire or disaster.

Underground Emergency: This is an emergency which may create a hazard to life due to:

1. Fire
2. Gas Explosion
3. Gas emissions from rock strata
4. Breakthrough into contaminated workings
5. Oxygen deficiency
6. Other emergencies requiring special services

Fire Procedure: A predetermined course of action put into effect to save lives and fight the fire during an underground emergency due to a fire. The procedure will include the Fire Organization and will indicate the duties of the Emergency Control Group.

Emergency Control Group: Consists of preselected personnel who direct and are responsible for all actions and decisions during an underground emergency. The group usually consists of the mine manager and assigned personnel.

Emergency Organization: This is the structural arrangement listing the duties and responsibilities of the Control Group during an underground emergency.

Notification Chart: List of people who will be notified in the event of an underground emergency. Besides certain company department heads, the chart will also include the Mine Rescue Officer and other Ministry of Labour officials. The number of people notified will depend on the severity of the emergency.

Policy

Objective: A five man mine rescue team shall be ready to go underground within fifteen minutes of arrival at the mine. Each mine should have equipment available such as Type N's or Demand Air Apparatus to equip personnel involved in the immediate evacuation (e.g. cagetenders, supervisory personnel).

Responsibilities and Arrangements

The following summarizes the primary responsibilities, authorized arrangements and designated authority in connection with mine rescue and recovery operations:

Minister of Labour is responsible for the number and location of mine rescue stations in the province.

Director of the Mining Health and Safety Branch has overall responsibility for mine rescue training in the province. He is responsible for the organization and equipping of the stations, the type of training given, and the appointment of mine rescue officers.

Chief Mining Engineer acts for the Director and is responsible to the Director for the field organization.

Area Engineer is responsible to ensure compliance with the regulations concerning the number of men and supervisors trained in rescue and recovery work.

Senior Mine Rescue Officer has direct responsibility to co-ordinate, inspect and standardize training and equipment; and supervise the activities of the Mine Rescue Officers throughout the province.

District Mine Rescue Officer for the Ministry of Labour is responsible for maintaining the equipment, and for the training of the mine rescue crews.

Mine Manager is responsible for having the required number of men and supervisors trained in mine rescue and in case of an emergency will head the Control Group for the direction of mine rescue and recovery procedures.

The cost of establishing, maintaining and operating mine rescue stations is paid out of the Consolidated Revenue Fund. Periodically the Workers' Compensation Board reimburses the Consolidated Revenue Fund from monies assessed and levied by the Board against employers in the mining industry.

The payment of the crews in training or during rescue and recovery operations is the responsibility of the individual employer.

The Mining Health and Safety Branch is responsible for mine rescue training and maintenance of mine rescue equipment, and will co-operate fully in case of an emergency, giving all possible assistance in obtaining men and equipment and in any other way possible.

Procedure for an Underground Emergency

All Ontario mines are required to have a fire procedure. Standardization is encouraged and basically all procedures are as follows:

- Any person detecting smoke, or locating a fire which cannot be immediately extinguished, notifies his supervisor or a designated person on surface.
- The designated person arranges to alert all personnel underground by means of the stench warning or other approved warning system.
- Upon receiving the warning all persons underground proceed to a predetermined area such as a refuge station, a shaft station, or an emergency escapeway, as stated in the Fire Procedure.
- When workers are required to go to a refuge station, they will adopt the procedure established for that refuge station.
- When workers are required to go to a shaft station they will adopt the established fire procedure.
- When workers are required to go to an emergency escapeway to surface they will immediately proceed to surface and report in accordance with the established fire procedure.
- In an underground or tower mounted hoistroom where the normal air supply may become contaminated a source of uncontaminated air shall be available to the hoistman and cagetender.
- The person who implements the fire warning system will notify mine management. Mine management will follow the Fire Control Procedure and advise persons on the Notification Chart that there is an underground emergency.

Mine Management has the responsibility to:

- Locate men underground and get them to safety;
- Locate and extinguish or isolate the fire;
- Ensure that the mine atmosphere and workplaces are in a safe condition before normal mining activity is allowed to resume;
- Ensure that the appropriate Ministry of Labour officials have been informed.

A Mine Rescue Officer will:

- Ensure that mine rescue equipment is available for use;
- Be available to give technical assistance;
- Ensure that the appropriate Ministry of Labour Officials have been alerted; namely, Senior Mine Rescue Officer, neighbouring Mine Rescue Station and Area Engineer;
- With his superiors, arrange for additional equipment or assistance as required.

Should assistance be required from another mine in the form of mine rescue crews or equipment from a substation, the mine seeking assistance should notify the Area Engineer and a Mine Rescue Officer. The two mines will mutually make the necessary arrangements regarding transportation, finances, insurance, etc. The maintenance of equipment is the responsibility of the mine rescue officer.

Procedure to Give Outside Assistance

If a request for assistance is received from outside the province, or from within the province but outside the mining industry the following procedure should be adopted:

Before any action can be taken, a formal request is required, i.e. a telegram to the Minister.

The following people should be notified:

Minister of Labour: His approval is required before assistance can be given.

Director: His authorization is required before assistance can be given.

Chief Mining Engineer will contact the Area Engineer and Senior Mine Rescue Officer.

Area Engineer will contact the Mine Manager and request assistance.

Senior Mine Rescue Officer will alert the Mine Rescue Officer in the area where the assistance will be coming from and coordinate the services of the Mine Rescue Station.

Mine Rescue Officer will be on standby to supply equipment.

Mine Management will alert its mine rescue crews and make them available to the Ministry of Labour.

At the discretion of the Minister of Labour, Ontario, all costs pertaining to the assistance are the responsibility of the mine seeking assistance. The Minister will make the necessary arrangements for workers' compensation coverage.

Procedure to Request Assistance from Outside the Province

A mine with an emergency and deciding it requires assistance from outside the province should employ the following procedure:

Mine Management will:

- Consult with the Ministry of Labour officials.
- Contact the outside mine and make a formal request for assistance.

Arrangements for transportation, insurance, Workers' Compensation Board coverage and other related costs must be settled between the two mines or companies.

Mine Rescue Officer will:

- Ensure that the mine rescue equipment is ready.
- Alert adjacent mine rescue stations in case more equipment is required.
- Be available to give technical assistance.
- Ensure that the appropriate Ministry of Labour officials have been notified.

Senior Mine Rescue Officer will advise senior Ministry of Labour officials and co-ordinate the services of the Mine Rescue Stations.

Chief Engineer or the Area Engineer will be in consultation with mine management and act as a liaison between the mine management and senior Ministry of Labour officials.

Director must approve request before mine rescue crews can be imported.

Minister of Labour: His approval will be required before a mine rescue crew can be imported.

Standard Practice for Mine Rescue Officers

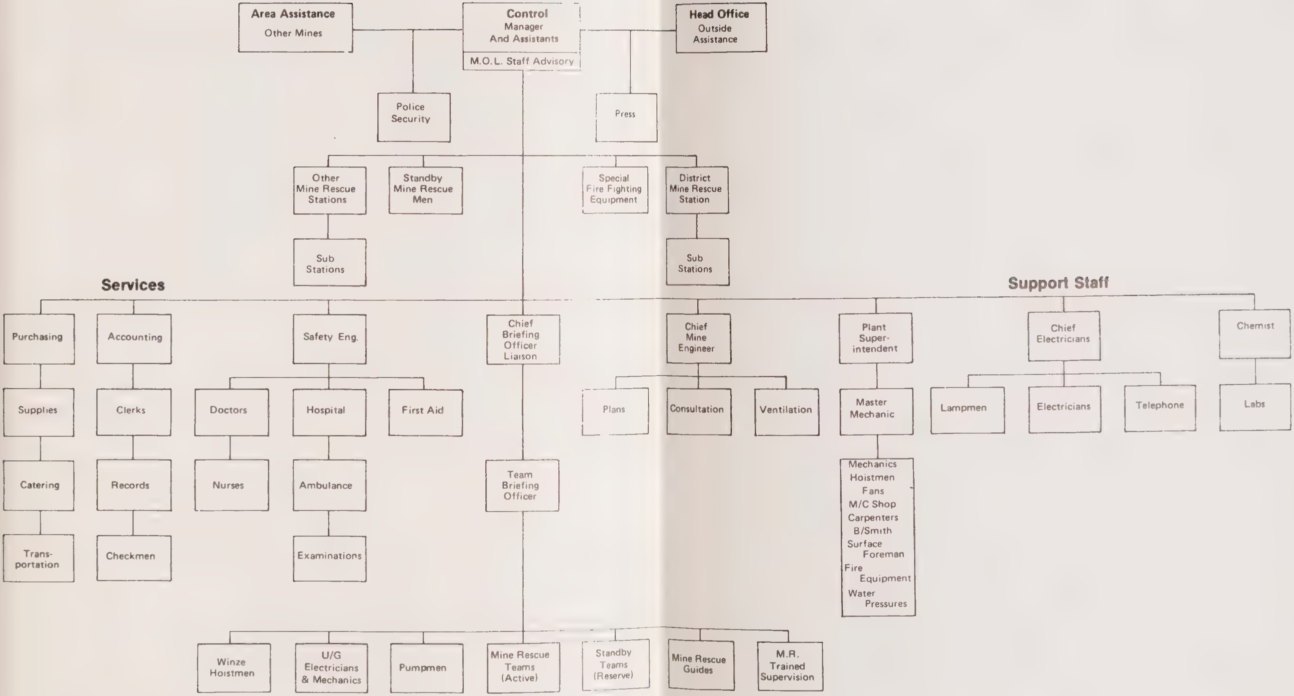
The following standard practices will be used by Mine Rescue Officers:

- Keys to the Mine Rescue Stations will be made available to mine managements.
- The Mine Rescue Officer shall provide a prepared schedule of training and monthly itinerary, indicating his whereabouts in case of an emergency.
- A minimum of 18 Drager BG 174 apparatus, with 3,000 psi in the bottles must be available at each Mine Rescue Station. Twelve will be located in the Mine Rescue truck if possible, and six in reserve at the Mine Rescue Station.
- The six BG 174 apparatus and complete standard mine rescue equipment must be readily available in the Mine Rescue Station and all the mines in the area dependent upon such equipment must be made aware of the arrangement.
- A written emergency procedure describing the practice in individual districts must be circulated to all the district mines and all other Mine Rescue Stations.
- Each Mine Rescue Officer must be familiar with the neighbouring districts, and the procedures must be standardized as much as possible for all districts.
- Whenever a Mine Rescue Officer leaves his district, the Senior Mine Rescue Officer, the Area Engineer, the local mines and the neighbouring Mine Rescue Officer must be notified.
- Unless special authorization is obtained from the Chief Engineer's office and the Area Engineer is notified, no two adjacent districts will be without the services of at least one Mine Rescue Officer.

Guidelines for Mine Rescue Officers and Mine Management

Several guidelines have been established for the benefit of the mines during an emergency. The company must be able to implement the fire procedure, organize and equip the mine rescue team for an underground emergency operation.

- Each mine should have a complete list of all Mine Rescue Officers, Mine Rescue Stations and their telephone numbers. If during an emergency the mine is not able to locate the District Mine Rescue Officer they should call another Mine Rescue Station.
- If upon the first call for assistance, there is no answer at the Mine Rescue Station, or the answering service takes the message, there should be no further delay and mine security or other designated personnel should be dispatched to the Mine Rescue Station to obtain the Mine Rescue truck or the supplementary equipment. Company vehicles can be used if desired for transporting the equipment.
- The Engineer of the Ministry must be notified of the emergency and will immediately ascertain that a Mine Rescue Officer has been contacted and that services are being provided. If such is not the case the Engineer will contact a Mine Rescue Officer.
- If the mine is served by a substation located at a neighboring mine, the fire procedure must include the mode of transportation and list the authorized personnel for obtaining the substation equipment.
- The company fire drill should include obtaining the mine rescue equipment available without any assistance from a Mine Rescue Officer.



Fire Organization Chart and Control Group

- All emergency apparatus and equipment available in the district shall be listed by each Mine Rescue Officer. This list shall be updated annually.

Guidelines for Mine Rescue Crews When Called Out For An Emergency

- All members of the mine rescue crews should, if possible, report ready for work fully equipped with suitable clothes, such as coveralls, boots, socks, hard hats, etc.
- No one should be permitted to work in irrespirable air without having been examined and found physically fit by a physician or, in the absence of a physician, by the most competent person present.
- No member should remain on one shift longer than six hours. During this period no man should be permitted to remain under oxygen longer than two hours, except in extreme emergencies.
- No one should be permitted to take a second shift until he has had at least six hours rest.
- Teams should be allowed 12 hours complete rest in every 24-hour day. Each rest period should be at least six hours.
- Standby time "out of oxygen" should be no greater than six hours in each 24, in addition to the six hours under oxygen.
- Plain, well prepared food, not too rich in sugar and fats, should be eaten in moderation. No food, including candy, should be eaten for one hour before taking active part in rescue and recovery work.
- Comfortable, clean sleeping quarters should be provided, where necessary, for members of rescue teams.

Appendix

Metrification

The International System of Units (SI) was adopted in Canada in 1980. The Mine Rescue Handbook has been revised to include both the British Imperial System of Measure (Br. Imp.) and the SI system.

Table of Equivalent Measures

Measure	British Imp.	S.I.
Weight	1 pound	0.453 kilograms
Linear	1 foot	0.3048 metres
Liquid	1 gallon	3.7853 litres
Volume	1 cubic foot	0.0283 cubic metres
Force	1 pound-force	4.448 newtons
Pressure	1 pound force/sq. inch	6.895×10^3 pascals

General Data

Metric Conversion

Measure of	To convert	Into	Multiply by
Pressure	atmosphere	bars	1.01325
Pressure	atmosphere	pounds/sq. in.	14.70
Pressure	atmosphere	kilopascals (kPa)	101.325
Pressure	Bar	kilospascals	100
Temperature	Celsius	Fahrenheit	9/5°C + 32
Length	centimetre	inch	0.3937
Length	feet	centimetre	30.48
Length	feet	metre	0.3048
Length	metre	feet	3.281
Length	yards	metres	0.9144
Volume	cubic foot	litres	28.3
Volume	cubic centimetre	cubic inches	0.06102
Volume	cubic metres	cubic yards	1.308
Volume	cubic yards	litres	764.6
Volume	litre	cubic inches	61.02
Liquid	gallons (Br.)	litres	4.5459
Liquid	gallons (U.S.)	cubic cm	3785.0

Drager BG 174 oxygen bottles are charged to 2,000 psi = 13,800 kilopascals = 138 bars. The capacity volume of the bottles at this pressure is 270 litres.

The safety cap on the oxygen bottle releases at 4,000 psi = 276 bars.

The capacity of the breathing bag is 6 litres or 6.81 quarts.

The constant flow metering device controls the flow of oxygen at around 1.5 litres per minute to the breathing bag. The reducing device admits air into the bag at 57 psi or 393 kilopascals (kPa).

A man at rest consumes approximately 260 cubic centimetres of oxygen per minute or 16 cubic inches per minute. On exertion this figure may be 8 times higher.

The cylinder of the Scott Air Pak Model 6000 A2M when charged to 13,700 kilopascals (kPa) or (1,980 psi) will contain 1,141 litres (40.3 cu. ft.) of air. The cylinder weighs 13 kilograms (29.5 pounds).

A jumbo cylinder of 244 cu. ft. (6.8 m^3) charged at 2,200 psi will supply a man with air for 6 hours. The 300 cu. ft. (8.5 m^3) cylinder charged to 2,400 psi is good for 8 hours.

One pascal (Pa) is the pressure which results when a force of 1 newton (N) is applied evenly and perpendicular to an area of 1 m^2. 1 Pa = 1 N/m^2. E.g. atmospheric pressure is around 100 kPa (14.5 psi).

One newton (N) is a unit of force which when applied for 1 second to a body having a mass of 1 kilogram (kg) gives it a velocity of 1 metre (m) per second.

One foot pound — quantity of energy that will raise a 1 pound mass to a height of one foot.